Using Q method and agent based modelling to understand hurricane evacuation decisions

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Statement

I hereby declare that this thesis has not been and will not be submitted in whole or in part to another university for the award of any other degree

Signature……..

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List of Acronyms

ABM	Agent Based Model
FEMA	Federal Emergency Management Agency
GEM	Galveston Evacuation Model
IPCC	Intergovernmental Panel on Climate Change
PMT	Protection Motivation Theory
SAR	Social Amplification of Risk
SEU	Subjective Expected Utility
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UNISDR	United Nations International Strategy for Disaster Reduction

UNIVERSITY OF SUSSEX

ROBERT DAVID OAKES Ph.D GEOGRAPHY

USING Q METHOD AND AGENT BASED MODELLING TO UNDERSTAND HURRICANE EVACUATION DECISIONS

SUMMARY

A significant minority of at risk residents in the USA do not evacuate from an approaching hurricane when they are advised to by local authorities. This causes unnecessary deaths, injuries and suffering; a situation which is likely to intensify under predicted climate change. This thesis argues that non-evacuation is not fully understood as both the academic and policy framing of the decision to evacuate is centred around technical and socio-economic approaches which assume that risk is objective and "rational" people will evacuate if they have the material means to do so. This thesis argues that rationalities are differentiated and decision making is also a process which is influenced by members of a social network. Therefore there is a need for a more constructivist approach to get a deeper understanding of the subjectivity of hurricane evacuation. In this thesis, the theory of reasoned action is used as the framework of decision making as it highlights the importance of subjective attitudes and subjective norms on behaviour.

A mixed methods case study of Hurricane Ike is used to analyse the evacuation of Galveston Island, Texas. Firstly a "Q" study was undertaken with 40 residents of Galveston, which unveiled four distinct subjective evacuation attitudes, demonstrating that people understand hurricane risk in different ways which impact on their decision to evacuate. The results of the Q study were then used to parameterise an agent based model, designed to investigate community level evacuation. The model showed that it is possible to explain island-level evacuation through the combination of subjective evacuation attitudes and subjective norms which can interact to produce emergent, or unpredicted behaviour.

This thesis represents a fundamental challenge to positivist approaches and clearly demonstrates the value of a more constructivist approach to understanding hurricane evacuation based on subjective evacuation attitudes and subjective norms.

Chapter 1: Introduction

1.1 Introduction

In the 30 years from 1980, it is estimated that globally 412,644 people died as result of hurricanes[1] (Doocy et al., 2013). In addition to the threat of death and injury from the wind, flooding and tornados associated with hurricanes there are further indirect threats caused by the failure of utilities such as electricity, water and telecommunications after a hurricane makes impact. As other services including healthcare and air conditioning depend on such lifeline systems to function, staying in an affected area post-hurricane can also have an injurious impact. As a result of these threats, evacuation, defined as a 'response to a perceived danger in his or her immediate environment in which he or she acts in an affirmative way to decrease the perceived risk to said danger by leaving the site of danger' (Burnside et al., 2007, p. 727), is normally seen as the most appropriate response to hurricane risk.

On average every decade 17.8 hurricanes make landfall on the Atlantic and Gulf Coasts of the United States of America (Blake et al., 2007), the evacuation from which presents a significant managerial challenge to elected and emergency officials. Hurricane Katrina infamously demonstrated that populations in the USA which are threatened by a hurricane make a wide variety of evacuation decisions, some of which result in injury and death. Whilst the majority of residents evacuated from Katrina, thousands remained in affected areas, unable or unwilling to leave their homes despite first warnings, then orders to leave. This resulted in the avoidable deaths of approximately 2,000 people. During and after Hurricane Katrina, there were two

[1] Cyclonic storms have different names according to the ocean in which they are formed. Storms formed in the Indian Ocean are known as cyclones, storms from the Pacific Ocean are known as typhoons and storms which develop in the Atlantic Ocean are named hurricanes. As the current study is focussed on the USA, the term hurricane will be used throughout this thesis.

dominant framings of the evacuation response. It was framed as a failure of risk communication as it was claimed that many of those who stayed were unaware of the danger to their lives (Lachlan et al. 2007). In this way fault is ascribed either to the authorities who did not inform the public of the risk effectively, or the members of the public who were viewed as irrational for deciding to stay and weather the storm despite the risk. The other framing of the evacuation was centred on race and poverty (Elder et al. 2007). As most of those who died in New Orleans were African Americans, an explanation emerged which described a group of people who were structurally constrained, and unable to leave due to inequality of wealth, knowledge and power.

1.2 The research problem

Such understandings of hurricane evacuation have contributed to a narrow range of policies which seek to maximise evacuation rates; namely better risk communication and evacuation assistance. It is assumed that if people think and act rationally, then when they are advised of a threat they will evacuate. According to conventional neoclassical economics and most policy makers, rational individuals should be able to keep themselves informed of the weather in order to determine the probability of being impacted by a hurricane, decide how serious the impact will be and make the decision to evacuate or not accordingly. Therefore evacuation can be encouraged by education about the risks inherent in staying, and effective communication of when it is necessary to evacuate (Morrow 2009). It is possible that some people do think in such a manner, but if the vast majority of the affected population is receiving the same information and thinking in the same way, evacuation decisions could be expected to be uniform. Conversely, the fact that not all threatened populations evacuate when they are advised to, and that some people evacuate when it is unnecessary, suggests there is heterogeneity in the way people conceptualise hurricane risk and make evacuation decisions.

Evacuation assistance refers to facilitating the evacuation of those members of society who are unable to leave, usually due to financial or health reasons. Often this translates into the provision of transport for those without cars, or medical assistance

for the infirm (Litman 2006). However, until now risk communication and evacuation assistance have so far been unable to encourage one hundred percent evacuation rates. This thesis will argue that there is a need for further research into evacuation behaviour as the experience of most hurricanes suggests that people understand and act on hurricane risk in a way that does not conform to public officials' expectations. Hurricane evacuation policies and models tend to simplify the evacuation decision making process, through making untrue assumptions about homogeneous attitudes, priorities and rationales. As a result policies do not address the range of issues which typically lead to a significant minority of residents (20-30%) deciding to ride out any particular storm (Redlener, 2006). The resulting overarching aim of the thesis is therefore to find an answer to the following research problem:

> Despite warning, why do a significant minority of affected residents not evacuate from hurricanes?

1.3 Climate change and hurricanes

It is especially important to improve understanding of hurricane evacuation, as it is likely that in the future the impact of hurricanes will be intensified through climate change. It is often assumed that an increase in sea surface temperature is likely to result in an increase in the frequency of hurricanes as the minimum sea surface temperature for cyclogenesis (26°C) will be exceeded more often. However, the complexity inherent in hurricanes means that sea surface temperature is not the only determinant of their formation and development. For example, it is believed that variation in vertical wind shear and mid-tropospheric moisture could actually result in less hurricanes forming (Vecchi and Soden, 2007). The latest Intergovernmental Panel on Climate Change (IPCC) Hazard Report concurs, predicting no change, or a decrease in global frequency (IPCC, 2012). Multi-model ensembles of the North Atlantic forecast that the period 2016-2035 will bring a 20% decrease in hurricane frequency relative to 1986-2005 (Knutson et al. 2010). As hurricane intensity is strongly correlated to thermodynamic potential, it is assumed that global warming will bring both an increase in the intensity of hurricanes and hurricane related rainfall (IPCC, 2012). Projections for

the North Atlantic predict a 45% increase in the number of major hurricanes (category 3 or above) in 2016-2035 compared to 1986-2005 and an 11% increase in precipitation in hurricanes, and 18% for tropical storms (Knutson et al. 2010).

The IPCC's latest projections are for a rise in sea level of 28 to 98cm by 2100 (IPCC 2013). Sea level rises will have the effect of increasing the height of storm surges which are forced inland due to the force of the hurricane's wind field (Dasgupta, 2009; Frazier et al., 2010). When sea level rise is factored into storm surge levels, the new hazard zone approximates that of a hurricane one category higher on the Saffir-Simpson scale (Frazier et al., 2010). This could mean a one metre rise in sea level would enable a 15-year storm to inundate land only currently flooded by 100-year storms (Kana et al., 1984). A recent study on New York projects that the combination of an increase in the intensity of hurricanes and a rise in sea levels, could mean that the flooding caused by a 100-year hurricane, could occur every 3-20 years in the future (Lin et al., 2012).

It is also possible that in future hurricanes will impact on a larger area of the USA.
The occurrences of Hurricane Irene in 2011 and Hurricane Sandy in 2012 have been put forward as possible evidence for climate change impacting on the hurricane belt, with the potential for the entire Atlantic Seaboard to be more severely impacted by hurricanes if there is a poleward shift (IPCC, 2012). This would place a much larger population at risk, in areas without the physical infrastructure, nor the experience to cope with a hurricane. Existing hurricane evacuation policies and practices are based on a Southern context, which assumes low population densities, access to cars and relatively high standards of living which might not be appropriate to a Northern, urban context. For example in New York City approximately 48.9% do not have access to a car, potentially making evacuation problematic (Cutter et al. 2007).

1.4 US population change

The challenge of forming hurricane evacuation policy is also likely to be intensified in the future as global population grows, with increasing numbers living on the coast

(Nicholls, 2006). In the United States the population at risk of hurricanes is increasing, with over 50% of the population now living within 50 miles of the coast (NOAA, 2011). All coastal areas of the United States are seeing an increase in population, with the Gulf States the areas of highest population growth (NOAA, 2011). In addition this increasing population will have a higher percentage of children, senior citizens, female headed households, ethnic minorities and mobile homes, implying both greater need for, and additional challenges to evacuation (Cutter et al., 2007).

1.5 Hurricane Ike

In order to address the research problem, the research for this thesis was conducted on evacuation in the face of Hurricane Ike which made landfall as a category 2 hurricane on the barrier island of Galveston, Texas in September 2008. Despite the apparent danger and warnings and orders to leave, it is estimated by the time of landfall, approximately 30% of the island's population had not evacuated and instead weathered the storm, leading to several deaths (Peacock et al., 2011). Research on Galveston suggests that due to climate change, by 2100 water level exceedance probabilities will double for the largest hurricanes such as Hurricane Ike and increase by six times for smaller storms (Dueñas-Osorio et al., 2012). On barrier islands such as Galveston, this change could be further amplified by the degradation of the integrity of the island itself as rising sea levels impact on the sand, washing it away and cause shorelines to migrate inland (Irish et al., 2010).

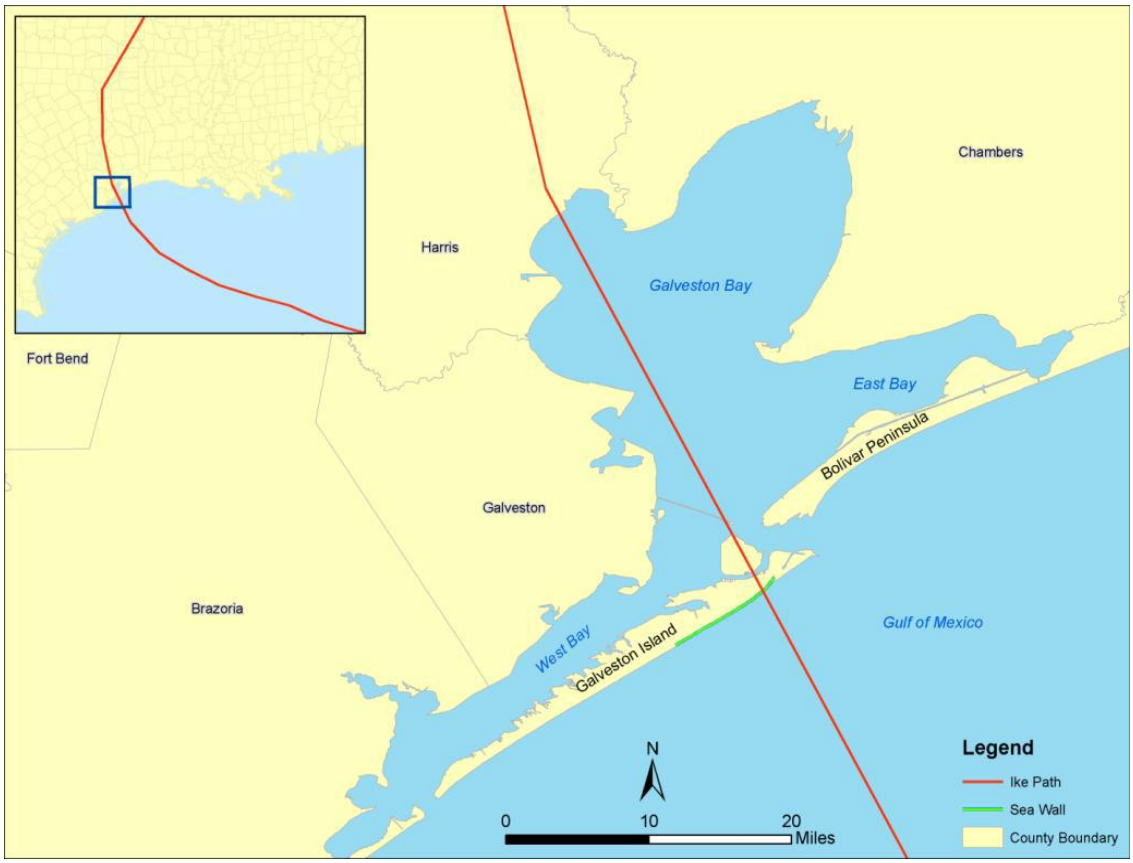

Figure 1.1: The case study location of Galveston and the course of Hurricane Ike. (Peacock et al., 2011).

1.6 Aims of the thesis

The documented aim for the state of Texas is to complete a full evacuation before the onset of pre landfall tropical storm force winds (FEMA, 2010). The Hurricane Ike Post Storm Assessment highlighted the idea that '… forecasters and emergency managers need to know how and when people will respond to hurricane warnings… Better knowledge about the attitudes and potential behavioural response of coastal residents is an important step toward designing relevant educational and evacuation programs' (FEMA, 2010, pp. 129–130). The report also states that '…above all evacuation behaviour research has to be multidisciplinary given the complexity of communication and decision making issues, economic and societal impacts, organizational and infrastructure constraints, and the dynamic nature of the evacuation responses' (FEMA 2010, pp.129–130).

This thesis accepts the challenges issued by the Hurricane Ike Post Storm Assessment by investigating the importance of attitudes and communication in a multidisciplinary way. The theory of reasoned action (TRA) is adopted for the framework of the thesis as it highlights the importance of attitudes and subjective norms in health related decisions (Fishbein and Ajzen, 1975). The thesis makes theoretical and methodological contributions through devising a multidisciplinary approach to investigate hurricane evacuation. A Q study is used to reveal subjective evacuation attitudes and an agent based model (ABM) is designed to simulate the complexity and dynamic nature of island-level evacuation decision making by using the subjective evacuation attitudes revealed by the Q study and combining these in a model that is also able to attend to the role of subjective norms and social networks. To the author's knowledge, a Q study has never been used in order to investigate hurricane evacuation, while the use of an ABM for simulating hurricane evacuation is a promising, if immature field. The combination of a Q study and an ABM has not been undertaken before, and this thesis seeks to demonstrate their compatibility and potential to be used to investigate hurricane evacuations and other environmental hazards.

The thesis also makes empirical contributions which challenge how hurricane evacuation is incorrectly framed under positivist technical and socio-economic approaches which assume people act in a homogeneous, rational way as defined by neo-classical economists. Instead the thesis shows that on Galveston, the evacuation for Hurricane Ike can be better explained through heterogeneity of subjective evacuation attitudes and the impact of subjective norms. In this way, a new and more sophisticated understanding of hurricane evacuation is facilitated. Policy related contributions follow on from the empirical findings and relate to how the findings from the thesis can shed light on how evacuation rates might be increased in the future through accepting the role that subjectivity plays in evacuation.

1.7 The structure of the thesis

The thesis is structured as follows. Chapter 2 presents a literature review which initially relevant to the research problem of hurricane evacuation rates. It goes on to assess

research on risk perception and then narrows the focus to analyse the literature on hurricane evacuation. It also considers the literature on social networks and how these might influence hurricane evacuation through subjective norms. After the literature is reviewed, some gaps in the literature are highlighted and research questions are formulated to address these areas. The chapter finishes by outlining the conceptual framework, based around the TRA, which is adopted for the thesis.

Chapter 3 introduces the island of Galveston and Hurricane Ike. It covers the physical and human geography of the island and explains why it makes an ideal place of study. The chapter recounts the hurricane history of Ike, the evacuation policy of the City of Galveston and the impact of the hurricane. The chapter also briefly surveys the extant literature on the evacuation from Hurricane Ike.

Chapter 4 presents the methodological framework and articulates how the research was designed to operationalise the conceptual framework via the adoption of two distinct methods (Q method and agent based modelling) in a case study approach. It highlights the necessity to adopt a mixed methods approach in order to answer the research questions. It is argued that a Q study is an ideal tool to reveal subjective evacuation attitudes, as it is designed for the study of subjectivity. Then ABMs are introduced as a tool for investigating the impact of subjective norms, as they are designed to analyse social interaction. It is argued that the Q study and ABM are complementary as both highlight subjectivity, with the former producing micro level inputs for the ABM which produces a macro level result.

Chapter 5 is the first empirical chapter which is concerned with investigating the subjective evacuation attitudes on Galveston. This chapter documents the Q study which was undertaken on Galveston in the summer of 2010 to investigate the reasons for residents' evacuation decisions in the lead up to the landfall of Hurricane Ike. The chapter recounts how the statements were sampled, the procedure for the sorting and the results of the factor analysis which revealed 4 distinct subjective evacuation attitudes.

Chapter 6 is the second empirical chapter and presents the ABM used to investigate island-level evacuation. The design of the Galveston Evacuation Model (GEM) is recounted, including the use of empirical data, theory and sensitivity tests. The results of the simulation demonstrate how island level evacuation can be explained through subjective evacuation attitudes and subjective norms. Sensitivity tests were then performed to investigate the impact of changes in subjective evacuation attitudes, social networks and subjective norms on the island-level evacuation result.

Chapter 7 is the main discussion of the thesis. It brings together the results of the two empirical chapters and relates them back to the literature review to assess how the findings of the thesis fit in with the relevant literature. The chapter also analyses the suitability of the tools for addressing the research questions. It also briefly discusses what light the thesis sheds on how policy might be able to encourage increased evacuation levels in addition to the limitations of the research.

Chapter 8 is the concluding chapter which summarises the thesis and its main methodological, theoretical, empirical and policy related contributions. The conclusion also proposes avenues for future research.

Chapter 2: Literature Review

2.1. Introduction

This chapter will cover the relevant literature on hurricane evacuation, and after revealing some important gaps in the field, introduce the research questions to be used throughout this thesis. The chapter begins by introducing the research problem which inspired this research. The second part of the chapter concentrates on how the academic literature has framed risk perception under technical, socio-economic, psychological and cultural paradigms. These paradigms are then used to examine the literature on hurricane risk perception. The first two approaches, technical and socio-economic are well established and have been widely studied. These can be termed "exogenous" (Adger et al., 2008), as they frame risk perception as mainly informed by external factors such as risk communication or the material ability to evacuate. Under these approaches, the agency of the individual is often represented as limited and individual subjectivity is ignored. The other two approaches, psychological and cultural are comparatively neglected in academic and policy circles. They can be viewed as "endogenous" (Adger et al., 2008) as they are framed as being the product of internal factors, and so identify heterogeneous subjectivities, and recognise more agency in the individual.

The third part of the chapter investigates the role of subjective norms which are communicated through social networks. Initially there is a review of the literature on the impact of norms and networks on decision making in general, then their impact of hurricane evacuation, focusing on literature which suggests people are able to influence the evacuation decision of other members of their social network. In parallel to the endogenous approaches to risk perception, a subjective norms and social networks approach also places emphasis on subjectivity and agency, and until recently

has also been neglected in both policy and the academic literature. The chapter concludes by introducing the framework of the thesis and how the theory of reasoned action (TRA) is used to frame decision making (Fishbein and Ajzen, 1975).

2.2 Exogenous and endogenous limits to responses to environmental risks

In an analysis of climate change adaptation, Adger et al. (2008) highlight the difference between exogenous and endogenous limits. Exogenous limits are defined as those 'imposed from "outside society" or limits where the risk can be quantified' (Adger et al., 2008, p. 337) and include ecological and physical, technical and economic barriers. They are attractive as they offer analytical functionality as they are amenable to climate modelling, innovation analysis and cost-benefit analysis respectively and are often characterised as being objective and absolute. On the other hand, endogenous limits are related to 'the ways in which societies are organised, the values they hold, the knowledge they construct and the relationships which exist between individuals, institutions and the state…and vary widely within and between societies' (Adger et al., 2008, p. 338). Therefore through the endogenous understanding, limits to adaptation develop from inside society and are subjective and heterogeneous. Adger et al. argue 'it is perceptions, values and norms that either enable or constrain action' (2008, p. 345). Such a view could be seen as optimistic, as within this understanding adaptation is not limited by factors outside of societal control. In order for this recognition of agency to have a beneficial impact, there is a necessity to identify the diverse and contested values and the heterogeneous nature of individual subjectivity to enable policy to encourage positive adaptation behaviour (Adger et al., 2008). This literature review will argue that this analysis of the climate change adaptation literature can equally be applied to the hurricane evacuation literature which also tends to neglect the impact of endogenous factors on evacuation decisions.

2.3 Paradigms of risk perception

In order to address the overarching research aim of why not everyone evacuates despite being warned of the dangers of remaining, it is necessary to consider how

hurricane evacuation decisions are made. There has been a great deal of research into how everyday decisions are made, representing a divide both within and between academic disciplines. To generalise, according to neoclassical economists, decisions are taken by economically rational agents who analyse the available information and make a decision to maximise individual utility. On the other hand sociologists have argued that decisions are constrained by social structures, psychologists believe that decisions are made through perceptions and attitudes, while anthropologists have suggested decisions are best viewed through the prism of culture.

Much of the literature on hazardous decision making is centred on risk perception, with near consensus on its importance, but disagreement as to how risk perception is developed (Horney et al., 2012). A general definition of risk perception is; 'people's beliefs about their vulnerability to danger or harm' (Sheeran et al., 2013, p. 2). In a recent review of the hurricane evacuation literature, Morrow (2009) highlights the difficulties in producing over-arching paradigms to understand risk behaviour. Nonetheless, she identifies 4 main paradigms as prominent in the risk literature:

1 The Psychometric Paradigm (Slovic, 2000), which explains risk through various dimensions; voluntariness, dread, control, knowledge, catastrophic potential, novelty, and equity.

2 The Mental Models Paradigm (Jungermann et al., 1988), which explains risk through applying relevant memories to new situations with the aim of making an informed decision.

3. Cultural Theory (Douglas and Wildavsky, 1982), whereby risk is explained as defined locally and informed through culturally specific understandings.

4. The Social Amplification of Risk (SAR) (Kasperson et al., 1988), which explains risk through a combination of technical, psychological, social and cultural factors.

Although this is a useful distillation of the hurricane literature, a couple of issues arise. Firstly, it is obvious that Morrow interprets risk perception as merely endogenous. Exogenous factors are only included to the extent that they affect endogenous factors. However, the exogenous paradigms continue to be relevant in both academia and policy. As such they are considered in the following review. Secondly, Morrow identifies the psychometric and mental models as separate paradigms, but in this review they are treated as one psychological paradigm as both are concerned with the process of cognition. Finally the SAR offers promise for further investigation as it integrates elements of other paradigms of risk, but is perhaps too specific to be determined a separate paradigm of risk perception for this literature review. Nonetheless, as an important contribution to the field, it is explored below, not as an agenda setting paradigm, but as a framework for decisions to be compared to the TRA.

The following review of the hurricane literature modifies Morrow's framework and distils the literature on risk perception into a different 4 paradigms (table 2.1). The first two, technical and socio-economic are positivist interpretations which regard risk as objective, are informed by the natural sciences and economics and tend to operate on the societal or structural level so can be viewed as exogenous. The last two, psychological and cultural are constructivist interpretations, regard risk as subjective and are informed by social sciences such as psychology, sociology and anthropology. They consider risk to be subjective as attitudes and cultural worldviews are seen to both define, and validate risks. They tend to operate on the individual or group level, and can be viewed as endogenous. Although all four paradigms are discussed in the hazards and hurricane literature, only the first two tend to be recognised by policy makers and are apparent in evacuation plans. This thesis does not take the position that psychological and cultural factors are more important than technical and socio-economic factors, rather that they can give a complementary understanding. This chapter will go on to explain how the psychological perspective can give a differentiated explanation of individual rationality compared to the technical approach. In a similar vein, a cultural understanding grants an alternative view that it is our culture, not our socio-economic group which affects our decisions.

Table 2.1: An alternative four paradigms of risk perception

Paradigm of risk	Risk seen as	Explanation for risky behaviour
Technical (Rogers et al.,1983) (Morrow, 2009)	Positivist Objective Exogenous	Message not received Irrationality
Socio-economic (Hewitt, 1983) (Wisner et al., 2003)	Positivist Objective Exogenous	Marginalised groups less able to perceive or respond to risk
Psychological (Adger et al., 2008) (Kahneman, 2012)	Constructivist Subjective Endogenous	Differentiated attitudes to risk
Cultural (Douglas and Wildavsky, 1982) (Beck, 1992)	Constructivist Subjective Endogenous	Culturally ingrained attitudes and norms regarding risk

Source: Author.

We can see evidence of each of these four paradigms of risk in writings in the aftermath of the Lisbon earthquake of 1755. Lisbon was at the time the fourth biggest city in Europe and a major economic and cultural centre, and its destruction brought about a concerted effort by Enlightenment scholars to find an explanation for the loss of life. As a result, the Lisbon earthquake can be understood as the very first social science study of a disaster (Dynes, 1999). Voltaire's poem on the earthquake stated it was humanity's fate to 'suffer, to submit in silence, adore and die' (Masters and Kelly 1993, p. 93). Although perhaps it is Voltaire's intention to explain the weaknesses of optimism, the poem can also be read as a technical understanding of risk as the earthquake is presented as *force majeure*, with the residents of Lisbon powerless against it. However, in correspondence with Voltaire, Rousseau distinguished between structural factors as opposed to purely natural occurrences. He recognised the significance of a population exposed to the event, but also the vulnerability of that population, therefore his understanding could be seen as partially socio-economic:

> Nature did not construct twenty thousand houses of six to seven stories there, and if the inhabitants of this great city had been more equally spread out and more lightly lodged, the damage would have been much less and perhaps of no account.
> (Masters and Kelly 1993, p. 110).

Rousseau also hinted at a psychological understanding of risk, by raising the potential negative impact of differentiated behaviour. This resulted in death due to a failure to evacuate after the first tremors; 'how many unfortunate people have perished in this disaster because of one wanting to take his clothes, another his papers, a third his money?' (Masters and Kelly 1993, p. 110). Voltaire later documented the people of Lisbon holding an *auto-da-fé* (act of faith) in the aftermath of the earthquake as a way of ensuring it would not happen again. Community leaders believed 'the burning of a few people alive by a slow fire, and with great ceremony, is an infallible secret to prevent earthquakes' (Voltaire, 2012, p. 20). This could be an example of a cultural understanding of risk, as a religious or superstitious explanation is given for the event.

Therefore it can be argued that as early as the 18th century, between these two great Enlightenment thinkers, the Lisbon earthquake was interpreted through the prism of four paradigms of risk. Depending on which explanation is advanced, the residents of Lisbon died due to their wretched luck, miserable accommodation, foolish behaviour or ailing civilisation. Nonetheless, for the majority of the quarter of a millennium since the Lisbon earthquake, the technical and socio-economic understandings of risk have dominated the academic literature to the detriment of the psychological and cultural understandings. Below is an account of how each of the paradigms of risk have been employed and explored in the risk literature.

2.4 The technical paradigm of risk perception

The technical paradigm of risk is characterised by a focus on the event or threat as opposed to the individual or society which is impacted. Risk is seen as a fact of life, which people should be able to avoid through rational behaviour. Risk is defined neutrally as the probability of an unwanted event occurring (Knight, 2005). The

etymology of the word disaster belies this understanding; “astrum”, the Latin root of disaster, is defined as an event arising from an inauspicious constellation of stars (Oxfam, 2008). This interpretation continues to be supported by the media and in political circles, as risks, hazards and disasters are frequently described as unexpected, unprecedented, unfortunate events when they occur in areas of high population density. Therefore under this understanding, risk occurs through the intersection of a hazard with exposure (figure 2.1).

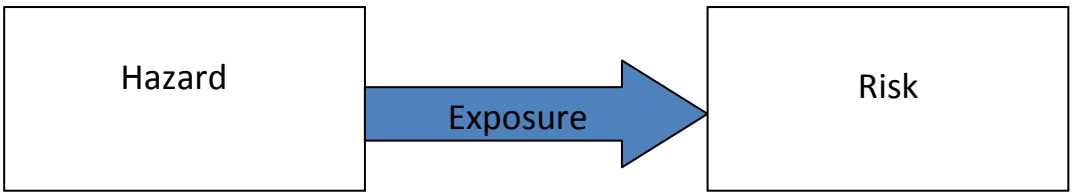

Figure 2.1: The technical understanding of risk perception. Adapted from the National Research Council (1983)**.**

The technical paradigm of risk is founded on the concepts of the rational actor and the objectivity of risk (Bradbury, 1989; Renn, 2010), while risk communication is central to risk mitigation (Morrow, 2009). For traditional economists, reason is everything, and choices are made in a rational way. This is explained through the concept of rational choice, sometimes termed “homo economicus” or economic man. According to such models, individuals are driven by utility maximisation; therefore when making decisions individuals consider the risk, benefits and relative probabilities of taking a course of action. The individual is viewed as an emotion free information processing unit, able to perceive risk, and then begin a linear process leading to action. Under the technical approach, when unpredictable or irrational behaviour occurs, it is explained through the deficit model. This means that unconformity is portrayed as the result of a misunderstanding of objective science, and can be overcome through improved information and communication. A refusal to engage in risk avoiding behaviour is therefore viewed as ‘a failure of the self to take care of itself – a form of irrationality’ (Greco, 1993, p. 361). The technical understanding of risk perception has evolved and most exponents of the technical approach now accept that we are bounded in our actions, as there are never an infinite number of options, rather there are limits to

what we can do (Simon, 1979). It has also been suggested that perceptions are not fixed, rather Bayesian updating enables us to maximise our expected utility by adjusting our risk perception as we receive more information (Kreps, 1988).

The most applied rational choice theory is subjective expected utility (SEU), which states the expected value received is a product of the benefit and probability (Savage, 1972). Another model which seeks to explain risk behaviour within the technical paradigm is protection motivation theory (PMT) (Rogers et al., 1983). PMT states that the motivation to take protective action is a result of threat appraisal and coping appraisal (figure 2.2). The threat appraisal is comprised of perceived susceptibility (how vulnerable the individual thinks they are to the threat and perceived severity (how serious the individual perceives the threat to be). The coping appraisal includes response efficacy (to what extent the individual thinks the action will deal with the threat), self-efficacy (to what extent the individual has confidence in their ability to carry out the action) and response costs (the perceived disadvantages of undertaking the action).

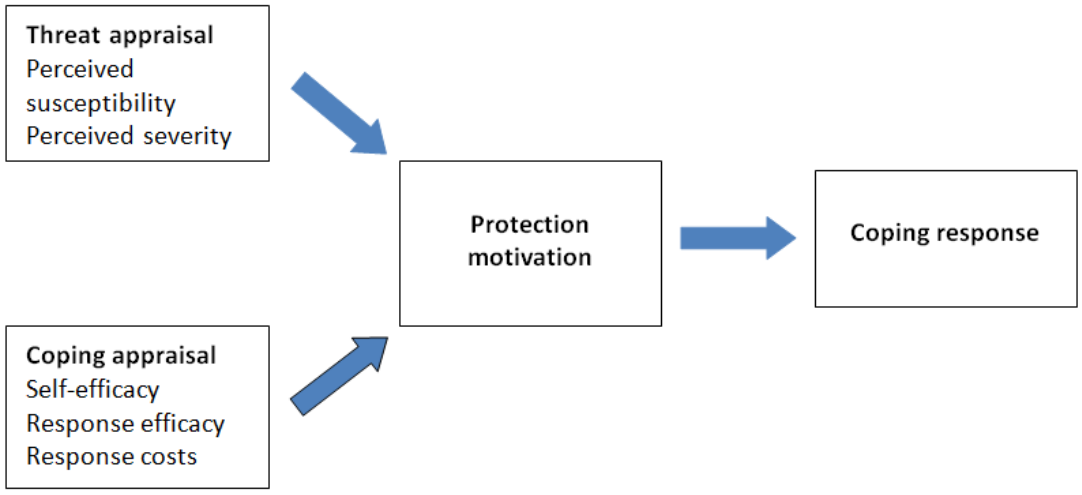

Figure 2.2: Protection motivation theory. Adapted from Rogers et al. (1983).

Within the technical paradigm, the concept of Governmentality (Burchell et al., 1991) has been used to explain how risk is framed through scientists and managed through bureaucrats. Expert knowledge is created by statisticians, meteorologists and engineers who define risk as value free and an absolute, objective truth. At the same time laypeople are dismissed as unscientific with inadequate risk perception (Lupton,

1999). As the state exerts more control over its population, it considers its role as one of managing and protecting. In this way, demographic groups can be identified as “at risk”. These groups are then seen as vulnerable, passive and in danger; requiring surveillance, knowledge or intervention (Ewald, 1991). Therefore under the technical paradigm of risk, people are not prescribed with characteristics which make them think and act as individuals. Risk is seen as objective, individual subjectivity is not recognised and individual agency does not exist.

2.5 The socio-economic paradigm of risk perception

The socio-economic paradigm of risk is shorthand for the socio-economic, ethnic and other demographic factors which are believed to influence risk. It is similar to the technical paradigm in that it also labels groups as at risk. It could be described as another positivist approach and risk is conceptualised as predominately objective. It was not until Dynes (1970) and later Hewitt (1983), that the technical approach was seriously challenged by the socio-economic approach. For them, the dominant technical paradigm acted as a barrier to understanding natural events and thus developing ways to alleviate them. Hewitt’s critique of the dominant research was centred on the idea of the disaster archipelago; a false separation of hazards from the society in which they take place. This separation was viewed as a construct supported by scientific and technocratic powers with the objective of taming nature and controlling society. Quarantelli (1988) cemented this link between the hazard and society claiming there is no such occurrence as a natural disaster, rather a conjecture of physical and social events. Wisner et al. (2003) supported and developed this concept. They argued natural events are triggers for disaster, which originate from social conditions, processes and institutions and a disaster only occurs when a vulnerable population is exposed to an extreme natural event. This is sustained by Pelling (2004) for whom a risk can only occur when a vulnerable population interacts with a hazard:

> While physical phenomena are necessary for the production of natural hazard, their translation into risk is contingent upon human exposure and a lack of capacity to cope with the negative effects that exposure might bring to individuals or human systems. (Pelling, 2004, p. 4)

In this way the socio-economic paradigm of risk perception is centred on the concept of vulnerability. According to the pressure and release model (Wisner et al., 2003), a disaster occurs at the intersection of vulnerability with a hazard (figure 2.3). This vulnerability is a result of social processes or the structures within a society. This model is also known as the "crunch model" as people are subject to increasing pressure on each side. Vulnerability is generated from root causes, dynamic pressures and unsafe conditions. Root causes are economic, demographic and political processes which affect the distribution of resources and power, dynamic pressures are the vehicle through which root causes are manifested into specific unsafe conditions which produce vulnerability to a hazard.

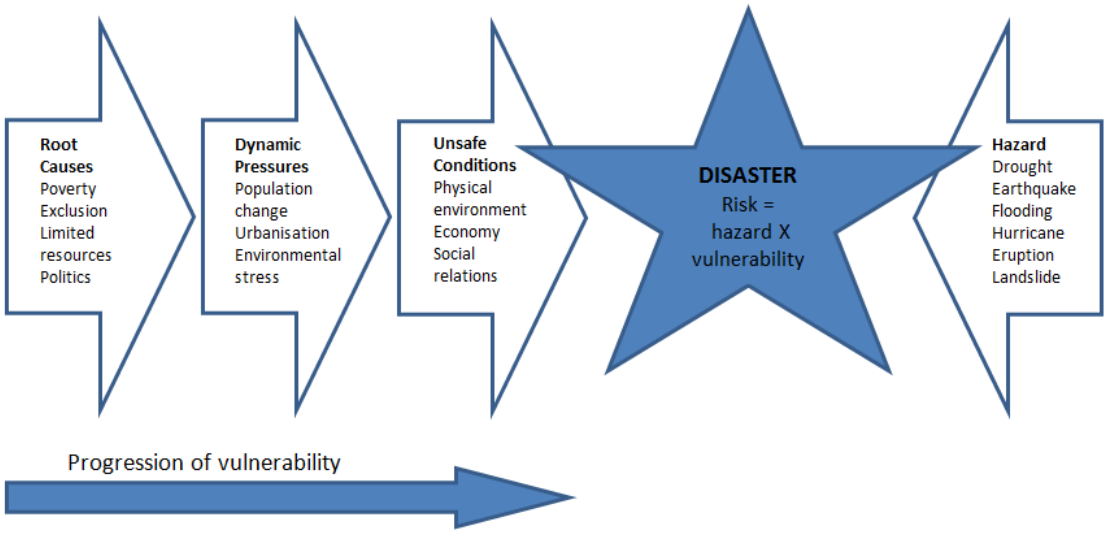

Figure 2.3: The pressure and release model. Adapted from Wisner et al. (2003).

It is therefore possible to argue disasters should not be understood as outliers, rather as logical events which reflect the characteristics of societies in which they occur. According to Oliver-Smith (1999), disasters must be viewed as "processual phenomena" not catastrophic events that occur in isolation. Therefore it is state policies, development and globalisation that cause disasters. Thus the socio-economic

paradigm moves away from the study of events, their proximate causes and effects, to the underlying structures which make disasters likely or even inevitable. Under the socio-economic approach, risk is typically represented as a function of the hazard, exposure *and* vulnerability. As a result people are thought to frame their understanding and response to risk according to their position within a society and the resources available to them (Elliott and Pais, 2006). The knowledge gap hypothesis supports this understanding as it states that people with a higher social economic status and higher levels of education have more access to information and so are better informed about risk due to their education and social capital (Tichenor et al., 1970). Under the socio-economic paradigm, policies for mitigating risk attempt to counter these structural factors by focusing on building resilience, adaptive capacity and disaster risk reduction (Pelling, 2011). While such efforts are crucial to improve conditions and responses to the threat of hazards, a problem with the socio-economic paradigm is that it assumes very little agency on the part of the individual, who is cast as a vulnerable victim of the demographic and socio-economic structures which control him. Little thought is afforded to internal subjective factors which might constrain decision making.

2.6 Positivism and constructivism

It is the position of this author that both the technical and socio-economic approaches to understanding risk are positivist. Positivists have argued social entities can be observed and studied objectively in the same manner in which the natural sciences are investigated. A positivist ontological stance claims that fundamental truths exist, and that the only valid knowledge is verifiable. As Comte (1848) claimed, when these truths or laws are established, they can be used to explain not only natural, but also social processes. This thesis rejects positivism as an unsuitable theory of knowledge, as it is reductionist because it does not recognise the complexity and heterogeneity in individuals and societies.

Therefore policies based on simplistic assumptions which derive solely from the positivist perspective are likely to fail. This literature highlights the importance of

subjectivity, as 'both technical evidence and external events can be interpreted in different ways, as such, there can be nothing automatically predictable about responses to environmental crises' (Fischer, 2003, p. 113–114). This thesis is not concerned with revealing definitive, objective truths, in fact it is the author's belief that such truths do not exist and the world is not objectively knowable. Instead the position adopted for this research is that in order to reveal the individual subjectivity which influences decision making, it is necessary to accept that multiple realities exist. Therefore a constructivist approach is adopted for this thesis. Constructivism is defined as 'the ways in which specific individuals come to interpret and make sense of their physical and social world and the personal viewpoints and knowledge structures that result' (Watts and Stenner, 2012, p. 42).

2.7 The psychological paradigm of risk perception

Supporters of the psychological paradigm of risk perception assert that as people interpret the world differently, they interpret risk subjectively; therefore it is a constructivist paradigm. According to theories of cognition (Kahneman, 2012), risk perception is differentiated across society not through misunderstandings or underlying social structures, but because people think in differentiated ways because their psychological make-up is different. For psychologists, perception is a process whereby each individual makes sense of their own reality. The idea that the world is how it appears was first challenged by Plato in the Parable of the Cave (1847). Berkeley (1906) developed the theme that the world appears to us in ways determined by our experience. In contrast to the technical paradigm of risk, under the psychological approach there is relativity in our perceptions; the nature of the experience is relative to the state of the perceiver and risk is therefore subjective. This has been termed symbolic interactionism, whereby people interpret information through their existing mental models (Blumer, 1986). This means that objectivity of risk is a myth as 'risk does not exist "out there," independent of our minds and cultures, waiting to be measured.' (Slovic, 1999, p. 690).

It follows that experts and laypeople will often have different perceptions of how risky a situation is (Slovic, 1987). Experts may define risk in a technical form but the public have more nuanced views which need to be integrated into risk analysis and policy (Slovic et al., 2002). Risk is defined subjectively by individuals who are influenced by a range of psychological, social, institutional and cultural factors (Lupton, 1999). As Ewald (1991, p. 199) puts it 'Nothing is a risk in itself; there is no risk in reality. But on the other hand, anything *can* be a risk; it all depends on how one analyses the danger, considers the event'. It is also claimed that perceptions and attitudes can be malleable (Petty et al., 1997), so risk behaviour is better viewed as a disposition as opposed to a trait (Bandura, 1999). Indeed research shows that definitions of self and self-interest can be context dependent and can change dramatically in events such as emergencies and disasters. This may cause people to stay behind after disasters and act as first responders as they experience a redefinition of self; from "me" to "us" (Drury et al., 2009).

Adger et al (2008), building on studies on climate change adaptation, have recognised the need for further investigation into the psychological factors which contribute to decision making under environmental threat. It has been found that people value personal or vicarious experience over expert weather forecasts (Marx et al., 2007), and a range of adaptation outcomes result from differentiated individual perceptions (Grothmann and Patt, 2005). Despite good intentions on the part of policy makers or project managers, policies designed to promote climate adaptation are ineffectual if they make false assumptions and are not tailored to stakeholders (Patt and Schroter, 2008). The central message of these papers revolves around the need to understand individuals' subjectivity in order to design policy to accommodate their heterogeneity. It is also possible that psychological differences might lead to differences in confidence in the ability to make a decision, as individuals with an external locus of control do not feel able to act on a perceived risk (Bandura, 1982). It has also been found that a belief in personal adaptation efficacy is positively correlated with successful climate change adaptation (Blennow and Persson, 2009).

The idea of rational man has been challenged by psychologists through research into heuristics. These short cuts, or rules of thumb take place below the level of awareness, so should not be viewed as conventionally rational decisions. Kahneman (2012) has produced decades' worth of experiments to show how heuristics enable us to take fast decisions. The first heuristic is known as the availability heuristic (Tversky and Kahneman, 1973). This describes how when we are making a decision, we are influenced by events which come more easily to mind, therefore perceived risk is influenced by how possible it is to imagine the hazard and how memorable past hazards were. This means that past experiences can influence behaviour by shaping future learning (Slovic, 1986), and if a satisfactory outcome results from a decision, it is likely the same decision will be taken when similar circumstances arise in the future (Eiser et al., 2008).

A second heuristic is known as representativeness. This posits that people often fail to distinguish between items of a similar type. This lack of recognition of asymmetry can result in a simplistic understanding of risk, assuming all threats are equal (Kahneman and Tversky, 1972). This is due to the law of small numbers which postulates that people are inclined to over-generalise from a small data set. This could result in personal experience leading to an underestimation of risk, overconfidence, and overreliance on infrastructure (Tversky and Kahneman, 1971). Finally there is the affect heuristic which demonstrates people are influenced by emotions, with value systems affecting their perceptions (Slovic et al., 2002). People are inclined towards one particular type of behaviour, and adjust their risk perception accordingly. This could mean for example, people are more likely to downplay the risks of smoking because they enjoy doing it. The influence of heuristics on decision making has been used as a justification for authorities to label these decisions irrational and wrong (Eiser and Van der Pligt, 1979).

Further biases have been highlighted to further explain non rational behaviour. For example, risk decisions are further biased by the tendency to overweight the probability of rare events, meaning people are not able to interpret probabilities in the same way as an economist might claim (Kahneman and Tversky, 1979). Prospect

theory has demonstrated that at low levels of risk, people are risk seeking for gains, but risk averse for losses (Kahneman and Tversky, 1979). On the other hand, Weinstein (1980) investigated the optimistic bias, and found that some individuals are likely to judge their risk to be lower relative to others and so believe “it won’t happen to me”. This can mean valid warnings are dismissed as false alarms (Spittal et al., 2005). It has also been argued that the type of risk affects the way it is interpreted. Some members of society tolerate higher risks if they believe the risks are controllable, familiar and voluntary (Fischhoff et al., 1978). Neuroscience has also made strides in understanding the cognitive processes involved in risk perception. It is suggested that human brains may be programmed to react to risk (Szpiro, 1997) and neural pathways enable us to feel before thinking (Ledoux, 1989). Physiological variety could suggest a neurological basis for differentiations in our reaction to danger (Ripley, 2009).

The psychological paradigm contains a great deal of research which asserts that people are not rational as defined by neo-classical economists; risk is subjective and therefore differentiated. It therefore gives a more nuanced approach to the technical paradigm which Wynne (1996) argues is based on optimistic fantasies about behaviour. Outside of mainstream economics, homo economicus is generally seen as illusory (Hayek, 2006). A poll by Edwards (1992) revealed that decision theorists unanimously dismissed SEU. A recent meta-analysis of experimental evidence found that risk behaviour was the result of a combination of technical and psychological factors (Sheeran et al., 2013). According to this study, risk is comprised of cognitive evaluation (whether it is considered risky), anticipatory emotion (i.e. fear), anticipated emotion (i.e. regret), and perceived severity (the perceived consequences of the hazard).

2.8 The cultural paradigm of risk perception

The final paradigm of risk perception, proposed by both anthropologists (Douglas and Wildavsky, 1982) and sociologists (Beck, 1992; Giddens, 1999) is that of culture. This approach shares commonalities with the psychological paradigm of risk as both stress the importance of individual agency, heterogeneity and subjectivity of perception. However under this paradigm, the personality of the individual is less important than

how he is affected by cultural settings and processes; individuals are not only assumed to follow their personal cognition, but also perceive risk according to cultural biases (Renn, 2010). There is a long history of cultural understandings of risky events extending as far back as the flood myths central to many civilisations and religions. The most prominent research on the cultural meanings of risk has been by Mary Douglas and associates through the cultural theory of risk. For Douglas, culture is defined as 'the publicly shared collection of principles and values used at any one time to justify behaviour' (Douglas, 1985, p. 67), and the cultural theory of risk suggests people are 'primed with culturally learned assumptions and weightings' (Douglas, 1992, p. 58) which have a strong influence on perceptions of environment, political, social and technological forces.

Work in the area of climate change adaptation has revealed the importance of culture on behaviour, and how preferences and worldviews are informed by culture (O'Riordan and Jordan, 1999). A study of Kiribati found the cultural values surrounding water were better predictors of adaptation than socio-economic factors, and policies could fail if they do not consider the cultural context (Kuruppu, 2009). Other research has found that in conditions of extreme stress people tend to look to their social and cosmic belief systems (Oliver-Smith, 1996). This may result in people perceiving risk in such a way as to support and conform to their existing beliefs (Darley and Fazio, 1980). McIvor and Paton (2007) agree on the cultural importance of risk, stating that worldviews are differentiated as they depend on experience, beliefs and expectations. These structures tend to be reinforced as people tend to have close relations with others who share their values (Newcomb, 1961). Thus it is possible to understand acting on information or taking advice as a preference which is culturally constructed, where the default position could be to adopt normative practices. It follows that providing "better" information or issuing unequivocal advice is futile if differentiated perceptions are culturally constructed. This is because expert advice might be viewed as irrelevant or inaccurate if individuals and communities interpret information through the prism of their culture. As a result some sources are seen as more trusted, reliable and competent than others. For this reason it has been suggested that

separate sections of the community can be reached by different people (Latimer Martin-Ginis, 2005).

While some technical experts may consider the non-acceptance of risk advice to reflect ignorance, if the cultural paradigm is correct, it might be better understood as a deliberate, agential decision (Michael, 1996). Risk positions can be important to people's self-identity within a community, as they may wish to be identified as different, giving them a special position in the milieu (Frank et al., 2011; Macgill, 1989). According to Giddens (1991) extreme situations may present opportunities to display personal qualities such as courage, ability or determination. In this way taking risks can be evidenced by the risk taker as a type of superiority, or self-realisation and a disaster subculture can develop (Lyng, 1990). On the other hand it has been found that some people seem to adopt what might be termed a fatalistic attitude towards hazards (McClure et al., 2007). Cultural explanations have been forwarded to explain why inhabitants of tornado prone areas of Alabama were found to feel their survival depended on fate, while people exposed to a similar threat in Illinois felt their own actions controlled their fate (Sims and Baumann, 1972). A similar effect of religious factors was found among Buddhists in post-tsunami Thailand (Paton and Tang, 2009).

The cultural paradigm claims that it is not people's ethnicity or socio-economic class which influence their decisions so much as their cultural environment. Although it is likely that socio-economic factors do have an influence on risk perception and attitudes, the cultural paradigm can tackle the issue from another, complementary position and as such is a vital tool to gaining a fuller understanding of how people perceive their subjective risk.

2.9 The exogenous paradigms of hurricane risk

Having considered the ways that the four paradigms of risk may inform risk perception, the following section of the literature review will discuss how the two exogenous paradigms have been investigated through the hurricane evacuation literature and the resulting impact on hurricane evacuation policy.

When a problem is seen as technical, it follows that its solution is also seen as technical. As such under the technical paradigm, hurricane proofed infrastructure, sea defences and improved detection are all utilised to deal with hurricane risk. Much of the research on hurricane evacuation also stresses the importance of technical factors on evacuation results. Under this conceptualisation, hurricane risk is represented as a function of hazard and exposure. This is an approach which is supported at the highest policy level, as the Hyogo Framework, produced by the United Nations International Strategy for Disaster Reduction promotes the production and dissemination of risk maps (UNISDR, 2005). This assumes when people are informed of the hurricane and their location relative to the storm surge and hurricane track models they will make informed, rational decisions to evacuate or to weather the storm (Morrow, 2009).

In support of this, it has been found that residents are more likely to leave when they are informed of the place and time of the landfall and the intensity of the hurricane (Perry and Lindell, 1991), and households with an evacuation plan are more likely to evacuate (Perry, 1979b). The way the message is communicated is also highlighted as being of utmost importance. If the warning is clear (Perry et al., 1981), consistent (Drabek, 1986) and frequent (Boggs and Drabek, 1968) the message is more likely to be believed and therefore influence evacuation behaviour. The message is also more likely to be believed if it comes from the authorities as opposed to friends (Mileti, 1975), and they are considered to have previously issued correct warnings (Drabek, 1986). Gladwin, Gladwin, and Peacock (2001) explain the importance of authority when considering evacuation behaviour. They claim that some residents evacuate because of an evacuation order, solely because it has come from someone with influence or from a respected public office. Fischoff (2006) has suggested six reasons why people would choose to stay in the path of a potentially deadly hurricane: failure to act sensibly, failure to understand risk information, failure to receive risk information, failure to believe risk information, communicators' failure to communicate effectively due to a lack of access to information and communicators' failure to acquire information. This explanation, largely centred on communication and interpretation, clearly views hurricane risk as objective.

Despite developments in hurricane meteorology, there is still room for improvement in the forecasting of intensity, wind, rain and surge (Willoughby et al., 2007). It has been found that over a third of residents "misidentify" their risk areas, and as a result the evacuation decision is more likely to be related to self-reported risk areas as opposed to official risk areas (Arlikatti et al., 2006; Zhang et al., 2004). Maps are used to inform populations of hurricane threat, although their interpretation is complicated by the complex relationships between height of surge, bathymetry and elevation (Arlikatti et al., 2006). The way the predicted path of the hurricane is communicated has also come under scrutiny. The diagrammatic representation of a hurricane's likely path or the "cone of uncertainty" has been criticised as people may be unsure of how to interpret it (Broad et al., 2007). The Saffir-Simpson hurricane classification scale (table 2.2) has also been criticised for giving a limited understanding of hurricane threat, as the category of hurricane is decided by the wind speed, meaning it does not consider the width of the hurricane, estimated storm surge or rainfall which are more reliable indicators of hurricane mortality (Kantha, 2006).

Table 2.2: The Saffir-Simpson scale of hurricane categorisation

Category	Sustained Wind speed (mph)	Storm surge (feet)
1	74-95	4-5
2	96-110	6-8
3	111-130	9-12
4	131-155	13-18
5	>156	>18

(Simpson and Saffir, 1974).

For advocates of the technical approach, the problem is not only that affected residents do not evacuate, but that residents of low flood risk areas often also evacuate. This flow of unnecessary, or "shadow" evacuation can prevent evacuation from the most threatened zones if gridlock results (Stein et al., 2010). Over the last decade, evacuation traffic has been one of the most popular areas of research into the technical paradigm of hurricane evacuation, and the increased power of computing has enabled complex and realistic simulations of the flow of evacuation traffic (Zhang et al., 2009).

It is clear that the production of accurate and well-timed information is a necessary condition for individuals to be able to make evacuation decisions. However it is incorrect to suggest that this is a sufficient condition. As people interpret the world differently, they interpret risk information subjectively. It is a mistake to assume that all individuals will respond in a homogeneous manner to hurricane threat; if this were the case 100% of people would attempt to evacuate when threatened.

Work on the socio-economic characteristics of disasters has been mirrored by studies which have shown socio-economic and other demographic factors act as barriers to evacuation from hurricanes (Peacock et al., 1997). Finance has been promoted as one barrier; it is argued that a lack of vehicle or cash for petrol, supplies or a hotel acts as barrier to action (Wolshon et al., 2005), and those with lower socio-economic status may be forced to remain in at risk areas as they cannot leave their job (Lindell et al., 2005). It is also claimed those with a lower socio-economic status could have difficulty receiving and complying with evacuation orders as 25-30% of Americans feel they would be unable to comply with a mandatory evacuation order unassisted (Redlener, 2006). However this idea has not been uncontested with Baker's (1991) study of a dozen hurricanes affecting Gulf and Atlantic coastal states finding no correlation between socio-economic status and evacuation result.

Ethnicity is also seen as a significant barrier to evacuation (Fothergill et al., 1999). It has been argued that minorities define risk differently (Perry, 1987), approach risk differently (Dake, 1992) and have different coping strategies (Peacock et al., 1997). For example, it has been shown Caucasians are more reliant on friends and family, while African Americans are more likely to rely on their religious faith (Elliott and Pais, 2006). Other studies have suggested that ethnic minorities are less likely to evacuate due to financial constraints, explaining non evacuation from Hurricane Andrew through a lack of resources, especially vehicles (Gladwin and Peacock, 1997). According to Perry and Mushkatel (2008) this can be explained by the interaction of ethnicity with socioeconomic status. Again the evidence is not unequivocal, with another study finding ethnicity was not a significant factor in flood evacuation compliance (Perry and Lindell, 1991). There is clearly some disagreement on the impact of socio-economic

factors on evacuation decisions. However, variety within socio-economic groups' behaviour suggests economic, ethnic, and demographic factors cannot fully account for non-evacuation (Dow and Cutter, 1998; Stein et al., 2010).

Since Hurricane Katrina, socio-economic and ethnic factors have taken prominence in the mainstream media as the most significant barriers to hurricane evacuation. The iconic images of this event were of African Americans wading through water, awaiting rescue on the roofs of the Ninth Ward and sheltering in the Superdome. These pictures combined with accounts of incompetence on the behalf of authorities and mistreatment at the hands of police. In the years since Katrina, academic and policy studies have consolidated this understanding stressing how underlying poverty and other social problems made New Orleans residents unable to evacuate, while a lack of trust in authorities lead to an unwillingness to follow official instructions. Studies on Katrina found a correlation was found between poverty, ethnicity and non-evacuation (Eisenman et al., 2007), and evacuation has been explained through a lack of financial or social capital, or a lack of trust in authorities (Elder et al., 2007). In both the media and in academia, African Americans were portrayed as being reliant on others for decision making and having limited options due to their position in society. They were seen as passive, irresponsible, inflexible and lacking agency (Stephens et al., 2009). Non evacuation by ethnic minorities has thus been described as death by 'political economy' (Price, 2008). Another study on Hurricane Katrina found evidence of the knowledge gap hypothesis, as Caucasians and men seemed to have a better understanding of how to protect themselves than other ethnicities and women (Lachlan et al., 2007).

Other demographic and life situation factors have also been forwarded as significant in explaining non evacuation. Single, young males with a low level of education have been found to be more likely to stay and weather the storm (Bateman and Edwards, 2002). Factors such as length of time living in a hurricane affected area and previous evacuation behaviour are also believed to have a bearing on likelihood to evacuate (Dash and Gladwin, 2007). The location of and type of housing is another factor which influences evacuation rates (Lindell et al., 2005), as residents at lower elevations and

closer to the water are more likely to evacuate, while residents in brick houses are more likely to stay.

Under the socio-economic framework little capacity to act is afforded to the individual, household or community. Agency and subjectivity is overlooked in analysis, as external environmental hazards or societal vulnerability are emphasised. People are more likely to be viewed as victims; dependent on assistance for development, building disaster resilience and for recovery and reconstruction. It is the poor and ethnic minorities and others on the margins of society who are highlighted as being at risk. As such they are routinely depicted as trapped in endless cycles of vulnerability and in need of external assistance for development, risk mitigation, and disaster recovery (Freudenburg, 1992).

The predominance of the two exogenous paradigms of risk in academia and policy seems to have resulted in two assumptions for policy with implications for hurricane evacuation. The first assumption derives from the technical understanding of risk. It posits residents act rationally; they make a cost benefit analysis and act in a health protecting manner and evacuate when aware of a threat. If risk is seen as being a function of hazard and exposure, it follows that if people are informed of the hurricane, their location relative to the storm surge and hurricane track models, they will make informed decisions as to evacuate or to weather the storm (Morrow, 2009). Under this appraisal, the solution is to better inform the population of the risk (Cole and Fellows, 2008). Theoretically, if communication is clear, people given the same information in the same circumstances should make the same decision (Morrow, 2009). The second policy assumption derives from the socio-economic understanding of risk. This hypothesises non-evacuators lack the financial or social capital to evacuate. Under this evaluation, the solution is for government to lay on buses, food and shelter to help residents evacuate (Litman, 2006). If enough services are laid on, in theory everyone should evacuate.

Evidence that the US policy makers focus on the exogenous approaches is provided by responses to Hurricanes Katrina and Ike. The Congressional Report on Hurricane

Katrina explained non-evacuation through economic factors and the failings of risk communication:

> The hurricane arrived over a weekend, at the end of the month. People on fixed incomes had little money for gas or food or lodging, making them more likely to remain in place and wait for their next check. Communicating via television or radio with families enmeshed in their weekend routines was difficult at best, as was finding drivers and other needed volunteers.
> (US Congress, 2006, p. x).

Within the report there was a recognition that a monolithic evacuation plan is problematic: 'one-size–fits-all plans proved impervious to clear warnings of extraordinary peril. Category 5 needs elicited a Category 1 response' (US Congress 2006, p. 2). However, this critique is limited to identifying the heterogeneous nature of hurricanes, but not of society, meaning individual subjectivity is ignored.

After Hurricane Ike, the City of Galveston has not drastically altered its evacuation policies and procedures, merely refined them. The City of Galveston want 100% evacuation, as evidenced by a recent statement by the City Manager; 'if it went perfectly, you would only have fire, police, emergency management, mayor, some of your department heads' (Daily News, 2014, p. 12). The City has developed a system to track the people who evacuate on city buses during a storm (Daily News, 2014). In future people will be issued with wristbands to track their movements and to ensure they are assisted to return home as soon as possible. This is indicative of another technical solution to the problem of evacuation.

Figure 2.4: The limitations of policy assumptions from the technical and socio-economic risk paradigms. Source: Author.

As figure 2.4 depicts, a combination of the technical approach (represented as risk communication) and the socio-economic approach (represented as evacuation buses) does not result in a 100% evacuation rate. Furthermore, the predominance of the technical and socio-economic over psychological and cultural paradigms acts as a limitation to a fuller understanding of behaviour and could be seen as contributing to another disaster archipelago (Hewitt, 1983).

This continued false separation of disasters from other fields, and the partitioning of specialties within disasters prevents the emergence of a holistic view. The need for more progressive, inclusive studies has been recognised by The Hurricane Ike Post Storm Assessment which calls for multidisciplinary research into hurricane evacuation (FEMA, 2010). An exploration of psychological and cultural factors might therefore be useful to build a more rounded knowledge of the reasons for non-evacuation. If research within the exogenous paradigms cannot explain all behaviour, perhaps approaches working within the endogenous paradigms can. It is this author's belief that an exploration of the psychological approach can give a more nuanced understanding to the way people perceive hurricane risk which embraces the subjectivity and agency of the individual. Likewise the cultural approach can give a subjective risk perspective on the influence of the environment in which an individual lives. The psychological and cultural approaches to hurricane risk are discussed below.

2.10 The endogenous paradigms of hurricane risk

Although still largely side-lined in policy, there is a growing literature which asserts the importance of psychological factors in the evacuation decision making process. The central theme in such research is the subjectivity of risk as residents are unlikely to evacuate when they feel safe. This could be because they believe the hurricane will not be severe, will not affect their neighbourhood, or will not damage their home (Riad et al., 1999). In considering the risk inherent in staying, residents may also be making a subjective judgement about the perceived threat of the hurricane with the perceived inconvenience or risk of leaving their homes. Evacuation can be uncomfortable as it tends to involve long distance travel. This situation is compounded for residents in

poor health, for whom travelling might be dangerous (Van Willigen et al., 2002). Alternatively, some residents will be more likely to leave if they believe their existing health condition could suffer if they remain in a hurricane threatened area (Eisenman et al., 2009). People might also feel unable to leave if it means leaving their pets behind (Heath et al., 2001). Therefore one should not think of one homogeneous form of rationality, but of multiple rationalities reflecting the subjective circumstances of different people. This means that for some people, under some circumstances it is rational to not evacuate.

Heuristics are further psychological factors which might influence evacuation decisions. In terms of the availability heuristic, the more memorable hurricanes tend to be those which have occurred recently or those which are more culturally ingrained. The representativeness heuristic means that people could fail to distinguish between hurricanes. In this way people are more likely to tar all hurricanes with the same brush, perceiving all hurricanes as deadly or harmless, perhaps depending on limited experience. They may not account for the role of chance and assume future events will mirror past events. It could be argued that the availability or representative heuristics impacted on decisions in the evacuation from Hurricane Rita. As Hurricane Katrina had just ravaged Louisiana, officials and residents alike were determined not to be trapped and mass evacuation occurred. An unnecessary “shadow” evacuation from Houston and other less exposed counties was called before residents of coastal areas could reach safety (Stein et al., 2010). This meant gridlock resulted, with evacuation journeys taking up to 24 hours. The traffic problems were compounded by unseasonably high temperatures and over 100 people died through heatstroke, chronic health conditions, automobile accidents and fires (Horswell, 2005). For this reason it has been claimed that “crying wolf” (Dow and Cutter, 1998) can make some residents unwilling to evacuate in the future.

The affect heuristic could mean that people are inclined to stay at home as opposed to evacuate, and therefore decide that it is not dangerous to stay (Slovic et al., 2002). Belief in one’s ability to execute an evacuation plan could also be important in final evacuation behaviour. Residents may feel unable to leave if they have low perceived

behavioural control (Ajzen, 1985). This could be reflected in a lack of self-confidence in the financial, social or physical capital necessary for evacuation. A similar idea has been put forward by Weinstein et al. (2000), who use the term trait anxiety to explain that some people seem to be unwilling to take responsibility for their actions.

The psychological paradigm of hurricane risk demonstrates not only that people think in different ways, but also due to heuristics these ways can be unpredictable and irrational as narrowly defined in neo-classical economics. This approach can therefore recognise the individual attitudes and subjectivity inherent in evacuation decisions.

For a cultural theorist, evacuation behaviour is a preference resulting from a culturally or socially constructed judgement of risk. Alternative rationalities make sense due to subjectivity which stems from differentiated lives, cultural frameworks, values and social structures. The importance of trust in hurricane evacuation has been highlighted. According to Wynne (1989), cultural differences could render expert knowledge as irrelevant or misleading and culture can impact on the way people interpret messages and trust signifiers (Nicholls and Picou, 2012). Residents are less likely to evacuate if they do not trust the authorities' judgement about the necessity of evacuation (Cordasco et al., 2007). This could refer to meteorologists, politicians, police or other municipal or state workers. The fear of looting is another reason not to leave which could be related to the culture of the resident as residents may feel the need to protect their property (Riad et al. 1999). This reason to stay may have increased in importance recently due to the media coverage claiming there was widespread looting in New Orleans after Hurricane Katrina (Tierney et al., 2006).

The emotional bonds which exist in a community could also be important. Some people may not evacuate as they envision that they can play a useful social role during and after the impact of a hurricane. They might want to be a source of emotional or material help in the community (Stephens et al., 2009). Despite popular media portrayals of anti-social behaviour such as looting, it is claimed disaster behaviour is generally pro-social (Drury et al., 2009). The motivations for pro-social behaviour are debated. Biology may mean that we are programmed to assist our kin (Hamilton,

1964). This may be in the expectation that help will be reciprocated in the future (Trivers, 1971). In this way prosocial behaviour can be viewed as a learned evolutionary behaviour. A related motivation is social, this comes from a feeling of empathy towards members of our community (Coke et al., 1978), the self-gratification we might feel when lending assistance (Cialdini et al., 1987) or a belief in justice, and the idea that helping can overcome injustice (Blader and Tyler 2002). Tierney et al. (2001) have highlighted the role of altruism and pro-social behaviour in the context of disasters.

There are a range of other factors which can be broadly classed as cultural, which influence hurricane evacuation. The desire to be in situ to repair a property could also be a reason to stay as residents may be unwilling to evacuate for fear not being allowed to get back to their homes and businesses immediately after the hurricane (Dash and Morrow, 2000). It is also claimed that there are some people who evacuate as a matter of course, and others who are proud to have never evacuated (Morss and Hayden, 2010). For some residents, it might be possible that fear brings about a need for affiliation and people seek safety in numbers and have a “hurricane party” (Christensen and Ruch, 1980). Another way in which culture may influence hurricane evacuation is through religious beliefs. For example it is thought that each time a hurricane threatens Bangladesh, a small minority feel they should not evacuate as it might be against Allah’s will (Haque, 1995).

The cultural paradigm of risk suggests that structures affect individual evacuation behaviour but it is not socio-economic structures, but cultural ones. This suggests that academics and policy makers cannot understand or predict evacuation behaviour through analysis of demographics, but through a deeper understanding of people’s culture. This approach, like the psychological paradigm therefore also acknowledges the importance of individual attitudes and subjectivity in evacuation decisions.

The main differences between the four paradigms of hurricane risk are shown in table 2.2. As this review of the paradigms of risk and hurricane risk has shown, alternative rationalities, which may be seen as irrational by the authorities, might make sense

when considering the wider context of the individual – life situation, cultural framework, values, preferences and social structures. Moreover, decisions are not necessarily taken on a conscious level. As a result, rationally predicted and intuitively taken decisions are often wide apart (Kahneman, 2012) and any policy based solely on the technical paradigm, rational choice and ignoring subjectivity is likely to be ineffective (Gowdy, 2008). Nor is an understanding of risk as a function of ethnicity or social class sufficient to drive successful evacuation policy. This thesis is not suggesting that psychological and cultural factors are more important than technical and socio-economic factors, rather that they are neglected by existing academic literature and hurricane evacuation policies. For this reason this thesis will incorporate the psychological and cultural paradigms of hurricane risk to investigate the impact of subjectivity.

Table 2.3: A summary of the paradigms of hurricane risk

Paradigm of hurricane risk	Approach to risk	Explanation for non-evacuation	Policy to increase evacuation
Technical (Fischoff, 2006)	Positivist Objective Exogenous	Risk not perceived Failure of homo economicus	Hurricane risk communication
Socio-economic (Elder et al., 2007)	Positivist Objective Exogenous	Marginalised groups are less able or willing to evacuate	Disaster risk reduction Evacuation buses
Psychological (Dow and Cutter, 1998)	Constructivist Subjective Endogenous	Differentiated attitudes result in differentiated behaviour	Lacking
Cultural (Stephens et al., 2009)	Constructivist Subjective Endogenous	Culturally ingrained attitudes result in differentiated behaviour	Lacking

Source: Author.

2.11 The role of subjective norms and social networks on decision making

As discussed above, the majority of research on hurricane evacuation revolves around a person's perception of risk, which can be explained as formed by technical, socio-economic, psychological and cultural factors. It has been argued in this review that

only the latter two consider subjective constructions of hurricane risk. However, risk is a social phenomenon (Smith and Kain, 2010) and decisions are not taken in isolation from the rest of society. People rarely make decisions as individuals but discuss with relatives, neighbours, friends, colleagues and religious leaders. Social milling occurs as people compare and evaluate information collectively (Mileti and Peek, 2002). The end result of these processes is that choices and judgements are less personal and more interpersonal, less independent and more interdependent. Therefore in addition to individual subjectivity, it is necessary to also consider the impact of subjective norms. Subjective norms are defined by Fishbein and Ajzen (1975, p. 302) as 'the person's perception that most people who are important to him or her think he should or should not perform the behavior in question' and the motivation to comply with these expectations. This means that those with a strong sense of group identity (Johnston and White, 2003) or fearful of social disapproval (Latimer and Martin Ginis, 2005) are more likely to be influenced by subjective norms.

As the social calculus of risk becomes more complex than that of the individual (Lowenthal, 2000), the impact of subjective norms on decision merits a separate treatment, related to, but distinct from culture. As described above, the cultural paradigm of risk perception stresses the impact of one's culture on decision making. However, the cultural paradigm focuses on the environmental conditioning of culture and does not lend sufficient weighting to subjective norms. Subjective norms can be conceptualised on a spectrum which can remain relatively constant, evolve over a long period of time, or evolve dynamically over short periods of time. Norms which are more constant form part of the cultural environment and were explored above, whereas those which adapt rapidly to the environment are considered as affecting subjective norms and are discussed in this section.

The structures through which subjective norms are communicated are social networks. These enable knowledge to both develop and flow (Wynne, 1989). In this thesis, social networks are defined thus:

> Individuals or groups linked by some common bond, shared social status, similar or shared functions, or geographic or cultural connection. Social networks form and discontinue on an ad hoc basis depending on specific need and interest.
> (Barker, 2003)

This definition has two aspects central to this thesis. Firstly, the network can exist socially, spatially or culturally. The advent of mobile communication devices and the increasing popularity of social media mean that communication is less spatially constrained than previously (Crowe, 2011). If people are no longer only communicating with others in their immediate vicinity, networks could potentially have a greater impact on decisions as ideas can spread more widely and more quickly than previously (Widener et al., 2013). It has been suggested that there is a threshold after which these characteristics of social networks mean they can become more important than the media in influencing risk behaviour. This has been termed the third person effect (Davison, 1983). Secondly, networks can be fluid and can evolve when necessary (Kossinets and Watts, 2006). This has been supported by research on emergency situations, as in times of distress people look to others for help with the decision making process. One example, is that the social interactions which victims of crime have immediately after the crime have been shown to have an effect on whether the crime is reported (Ruback et al., 1984).

2.12 The role of subjective norms and social networks in hurricane evacuation

The window of time between a hurricane entering the Gulf of Mexico and making landfall on the coast of the USA can range from several days to a week. This means there is great scope for communication between residents, and networks are likely to play a much greater role than in quicker onset hazards which afford less preparation time. The impact of social networks and subjective norms on hurricane evacuation has a history going back sixty years. Killian (1954) claimed that more households stay when their neighbours do so. These findings concur with Katz's (1957) hypothesis that persuasion is an interactive process, the success of which is driven by groups. It was later found that 30% of people discussed evacuation with non-family members (Moore,

1963). A review of research conducted in the 1970's found that 16-30% of evacuators were influenced by their friends and family (Christensen and Ruch, 1980).

A recent study on Hurricane Katrina revealed that for 52% of the subjects interviewed, interpersonal connections were the most important sources of information at the time of the evacuation (Taylor et al., 2009). This study is critical of explanations of hurricane evacuation which neglect the role of collective behaviour. For Taylor, the overriding factor in the decision making process was social networks, as decisions are not taken in isolation, but are inherently social. She also draws attention to the role of "opinion leaders". These informed, respected individuals (be they family members, friends, media personalities or politicians) have an especially strong influence on evacuation decisions. Therefore it is not just the power of the message, but the influence afforded to the messenger which will determine if advice will be taken. It has also been found that when people experienced enhanced fear they are more likely to conform to subjective norms (Darley, 1966). A stronger subjective norm could therefore combine with a fluid and evolving network (Kossinets and Watts, 2006) as a hurricane approaches landfall to increase the impact of peer pressure on the evacuation decision.

It seems the more social contacts one has and the more ties to the community, the more likely you are to receive a recommendation to evacuate (Perry, 1979). On the other hand, non-evacuators are likely to have smaller social networks (Boggs and Drabek, 1968). Therefore in the event of a hazard, the smaller the social network, the less chance of receiving information and assistance in evacuation. Network size has been the subject of much debate. An individual may have dozens of people in their milieu, however the number of people in that network who are likely to influence a decision is smaller, while the contacts who might contribute to providing support is probably smaller still. A recent survey on the USA found that the mean number of core discussion ties was two (Hampton, 2011), although this is likely to be an underestimate of social network size as there are likely to be people aside of our core ties with whom we communicate, and so are capable of influencing decisions. There has also been research which suggests that the number of contacts in people's social network might be increasing due to the impact of communication technology and social media. For

example, instant messaging is typically used to maintain a network of between three and five people (Kim et al., 2007).

A further role of social networks is to provide access to resources for those at risk, perhaps lending assistance to take action (Hobfoll and Stokes, 1988). It was found individuals with “weaker” social support evacuate less than residents with “stronger” social support, due to less access to information and material assistance (Riad et al., 1999). According to this study, it was not so much a question of the quantity of people in the network, rather the quality of the resources offered by the network. It is also important to realise that not all contacts have the same influence over decisions. Trafimow and Fishbein (1994) make the distinction between general and specific referents; the latter are particularly close family or friends who are likely to have a greater impact on decisions.

If it is accepted that evacuation decisions are influenced by subjective norms which operate within social networks, it is reasonable to assume subgroups of the population with distinct subjective norms and social networks might have different rates of evacuation (Moore, 1963). It has been claimed that African Americans are more likely to evacuate due to the influence of subjective norms as they often possess larger kinship networks compared to Caucasians (Perry, 1979). It has also been argued that ethnic minorities integrate their elderly into their communities, leading to increased evacuation (Quarantelli, 1985), although other research has found older people are less likely to evacuate (Perry, 1979). This might be due to the subjective evacuation attitudes described above, or could be because older people might have narrower social networks and therefore receive less information and social support.

Social networks have an impact on the individual decision to evacuate or not, through the spread of risk information, peer pressure and assistance with evacuation. In a recent review of the evacuation modelling literature, Murray-Tuite and Wolshon highlight the need to conduct interdisciplinary research as ‘social scientists have a better understanding of behavior, behavioral theories, and risk perception that are critical to developing quality models for evacuations’ (Murray-Tuite and Wolshon,

2013, p. 40). They also acknowledge the need to investigate the impact of social media on models. It is probable the impact of networks has increased as social media has become more popular. Risk information can be disseminated through social media such as Facebook and Twitter, therefore it has the capacity to accelerate alerting of the public, contact hard to reach sub-populations and guide people towards further information (Crowe, 2011). There is one study, published towards the end of the research for this thesis which attempts to simulate the impact of social networks on the decision to evacuate (Widener et al., 2013). This study is further discussed in chapter four.

2.13 The research questions

In their work on climate change adaptation, Adger et al. (2008) have critiqued the understandings of risk which locate the barriers to adaptation firmly outside, or exogenous to individuals. For them limits to adaptation should also be viewed as endogenous as they can come from within individuals and cultures. This review of the literature has demonstrated that the psychological and cultural paradigms of hurricane risk which recognise the subjectivity of risk and individual agency in decision making are relatively neglected in both policy and academia. Instead most evacuation policies and studies on evacuation tend to focus on the technical and socio-economic paradigms of hurricane risk which treat risk as objective and afford little agency to the individual. Paton et al. (2010) argue that there are a myriad of factors which may influence hazard event decisions which are unacknowledged by existing policy:

> Decisions to act are determined by how people interpret hazard events and related information to render them meaningful in the context of experiences, beliefs and expectations that are forged, changed and sustained through their social relationships with family, friends, other community members and civic agencies.
> (Paton et al., 2010, pp. 184–5).

This literature review has revealed the importance of 'experiences, beliefs and expectations' or subjective attitudes which can be studied through the psychological and cultural paradigms of hurricane risk perception. The review has also highlighted research on the impact of subjective norms and social networks, arguing that decisions are not taken in isolation from the rest of society. It is the position of this thesis that subjectivity is also 'forged, changed and sustained through...social relationships'. With the growth of social media it seems logical that subjective norms and social networks will become increasingly important in hurricane risk decisions in the future. However until recently there have been few studies which assess the impact of subjective norms and social networks on the decision to evacuate.

The research problem highlighted in the introduction was as follows:

> Despite warning, why do a significant minority of affected residents not evacuate from hurricanes?

Following a review of the literature, it is now possible to discern two distinct but related research questions, around which to focus the research of the thesis:

> 1. How do subjective evacuation attitudes affect hurricane evacuation decisions?
>
> 2.a. How do different subjective evacuation attitudes combine with subjective norms to create large scale patterns in hurricane evacuation?
>
> 2.b. How might changes in subjective evacuation attitudes, subjective norms and social networks alter large scale patterns in hurricane evacuation decisions?

The two questions are complimentary as the first gives a micro or individual level understanding, while the second gives a macro or societal-level understanding. The following section will address the framework which will be adopted to answer these questions.

2.14 The theory of reasoned action

Kasperson et al. (1988) have united some of the paradigms of risk and the role of social networks into a decision making framework known as the social amplification of risk (SAR). According to SAR, social roles and group membership determine the information selected by individuals as salient. Therefore messages have meaning within a socio-cultural context and interpretations which are consistent with existing values are amplified, while those inconsistent are ignored or diluted. According to SAR, there are several processes of amplification, with "social stations of amplification" which equate to subjective norms. Although SAR is a comprehensive understanding of risk, it is the author's contention that while it attempts to include the paradigms of risk highlighted above, they are organised around the technical approach. The focus is on the communication of risk, and it has been argued that the term amplification suggests that there is a true and an objective risk which is altered through social processes (Pidgeon and Henwood, 2010). As a result the SAR framework does not allow enough subjectivity to be used to answer the research questions for this thesis.

A theory of decision making which does focus on subjectivity as it incorporates subjective attitudes and the impact of subjective norms, is the theory of reasoned action (TRA) (Fishbein and Ajzen, 1975). TRA, like the rational choice model also suggests that actions are largely a function of their behavioural intentions. However, TRA has a different understanding of the way these intentions are formed. In rational choice models, intentions are the result of a calculation of the risks and benefits which may occur due to an action. In the TRA, intentions are formed through a combination of attitudes and subjective norms concerning behaviour (figure 2.5). The attitude towards the act or behaviour is the first component of the TRA. Fishbein and Ajzen's (1975, p. 8) definition of attitudes as 'a latent or underlying variable assumed to guide or influence behaviour' will be used in this study. Such latent or underlying variables inform how risky an individual perceives hurricanes in general to be. Attitudes are a function of beliefs about the outcome of a specific behaviour combined with an evaluation of the likely result of the specific behaviour. This means that latent or underlying variables can interact with information to form new attitudes.

In addition to attitudes, the other main determinant of behavioural intention according to the TRA is the impact of subjective norms. Subjective norms are defined by Fishbein and Ajzen (1975, p. 302) as 'the person's perception that most people who are important to him or her think he should or should not perform the behavior in question' and the motivation to comply with these expectations. This means that the individual is influenced by what his or her significant others want him or her to do. Variables outside of the model are assumed to influence behaviour only to the extent that they influence attitudes and subjective norms (Fishbein and Ajzen, 1975).

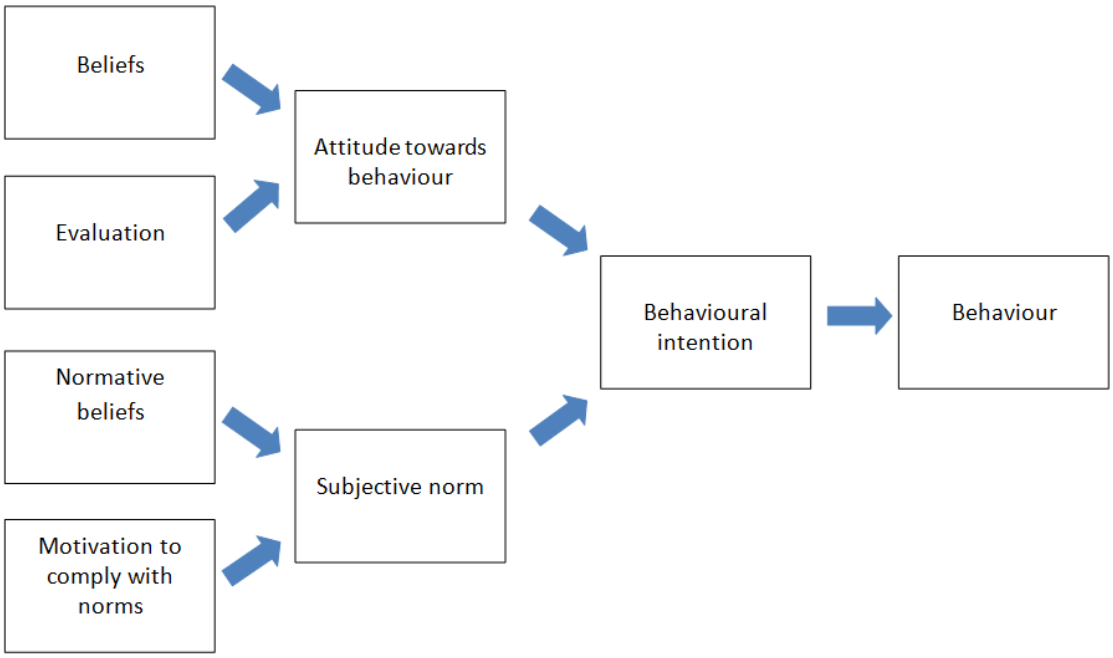

Figure 2.5: The theory of reasoned action. (Fishbein and Ajzen, 1975).

There are three conditions which must be satisfied in order for the behavioural intention to lead to behaviour (Fishbein and Ajzen, 1975). Firstly there needs to be close "specificity" between the intended behaviour and the actioned behaviour. This means that the focus needs to be on a particular behaviour (evacuation) as opposed to the result of the behaviour (safety). Secondly there should be "stability of intention"; there should not be a long delay between the production of the intention and the execution of the behaviour, as intentions can be altered through new information and perception. The final condition is that the behaviour should be one over which the

person has volitional control; if a behaviour requires resources beyond the means of an individual, or is dependent on another event or third party, there is likely to be a disconnect between the intention and the behaviour.

Unsatisfied with the issue of volition, Ajzen (1985) subsequently developed the theory of planned behaviour (TPB). This is based on the TRA with the addition of perceived behavioural control which influences both behavioural intention and behaviour. Intentions are affected because people might believe they have a lack of resources to carry out an action and so lose motivation. Behaviour is affected when these resources do in fact act as a barrier. A comparison was made between the two theories by Madden et al. (1992). In their study they found that in general the TPB explained behavioural intentions better than the theory of reasoned action, but only in the presence of barriers to volitional control.

Whether a person considering evacuation has volitional control is debateable. On the one hand, exponents of the socio-economic paradigm of risk would argue that a resident who does not have a vehicle might not have the means to evacuate independently. However, this thesis takes the position that in general residents in the USA *do* have the means to evacuate – although that means may be through reliance on family, friends or government buses. In other words, the fact that a resident wants to evacuate is not limited by material factors, as they can normally get support for evacuation. The TPB was designed to consider lifestyle choices on health, when it is debateable whether a person has control over a situation. For example, dieting or giving up smoking requires will power, without which a person might struggle. When considering evacuation, there is not usually an addiction or craving to overcome, therefore it can be assumed to be under the person's control. Therefore self-efficacy was not considered to be of sufficient importance to directly impact on intentions to act. For this reason it was decided to use the TRA and this study assumes that residents are able to undertake the decision to evacuate if they want. Self-efficacy still has a role in the framework, but only as far as it influences attitudes. Therefore it is assumed that a person is more likely to exhibit an attitude unfavourable to evacuation if they perceive that they might have difficulty in evacuating.

In a survey of studies using the TRA, Sheppard et al. (1988) found the model 'performed extremely well in the prediction of goals and in the prediction of activities involving an explicit choice of alternatives' (Sheppard et al., 1988, p. 338). TRA has also been used to investigate hurricane evacuation (Kang et al., 2007), with surveys to compare evacuation intentions before, and evacuation results after Hurricane Lili in 2003. They concluded that TRA is well suited to explaining the decision to evacuate as the decision is dichotomous; people either decide to evacuate or stay. It found a strong correspondence between behavioural intentions and actual behaviour despite the interval between two surveys. It can be assumed that when the difference in time between intention and action is minimised the correlation is stronger.

2.15 The framework of the thesis

One of the weaknesses of the TRA is that it does not specify the evaluations which are performed to form attitudes. For this reason it was decided to incorporate PMT (Rogers, et al., 1983) into the framework of the thesis. According to PMT, decisions are made through a combination of threat appraisal and coping appraisal, the later formed by response efficacy and self-efficacy. Therefore including efficacy means that the TRA is strengthened. Sheeran et al., (2013) have argued that PMT does not have a wide enough understanding of risk. For them risk appraisal is comprised of risk perception (the cognitive evaluation), anticipatory emotion (fear), anticipated emotion (regret), and perceived severity (the consequences) (Sheeran et al., 2013). They found each of the factors had a medium to large effect on the risk appraisal. For this reason, it was decided to add anticipatory emotion and anticipated emotion to threat appraisal into PMT.

The result of incorporating these developments into the TRA is shown in figure 2.6. In the framework it is assumed that an individual has an underlying belief about evacuation; essentially they will either be for or against it. When warned of an approaching hurricane, the individual appraises the risk and then decides whether it is sufficiently risky to warrant an evacuation. The individual also considers the coping efficacy of the action of evacuation and his ability to carry out the evacuation. In this

way some aspects of the technical and socio-economic approaches to risk are included in the model. However, it is important to note that they modify, but do not determine behaviour. For example, an individual who recognises the risk, but has a negative belief about evacuation might evacuate but might not. Likewise another individual who believes evacuation will work and is possible still might not evacuate if they are not favourable to it. As a result in this model, evacuation attitude recognises both individual agency and heterogeneity; this means it recognises the subjectivity of the individual.

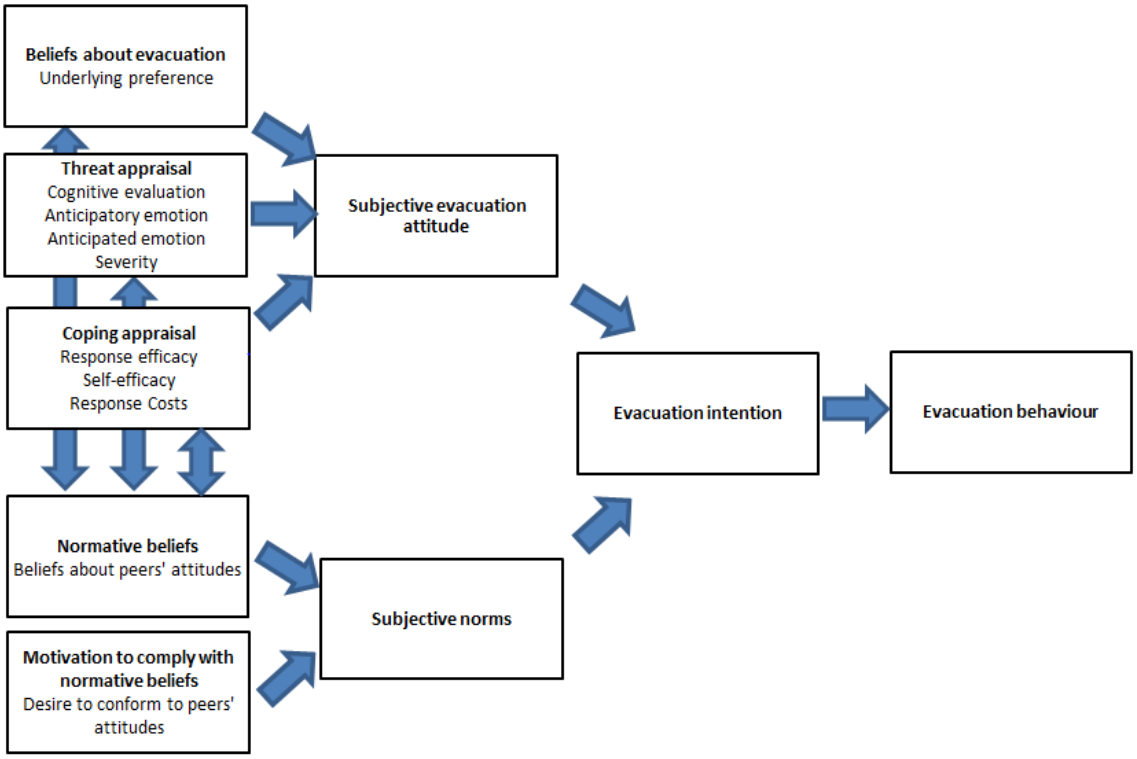

Figure 2.6: The framework of the thesis. Adapted from Fishbein and Ajzen (1975), Rogers et al. (1983) and Sheeran et al. (2013).

The TRA's understanding of subjective norms has not been modified for this thesis. Subjective norms concerning evacuation are understood as normative beliefs concerning evacuation and the motivation to comply with these beliefs. Evacuation intentions are therefore formed through subjective evacuation attitudes, which might then be altered by subjective norms. Beliefs about evacuation, threat appraisal and coping appraisal are all linked to normative beliefs as it seems logical that norms are formed and developed through these processes, which in turn are each modified by

norms. In the framework it is assumed that evacuation intention equates to evacuation behaviour in line with the findings of Madden et al. (1992).

2.16 Conclusion

The chapter began by reviewing the literature on hazard risk and how it has been applied to the problem of hurricane evacuation. The predominant explanations for risky behaviour have been, and continue to be framed by technical and socio-economic understandings of risk perception which frame risk as objective. As a result hurricane evacuation research has tended to concentrate on informing those at risk and encouraging them to evacuate. This has translated into two main policies; a concerted effort to improve information about hurricane risk and attempts to give material evacuation assistance to those strata of society considered more vulnerable. While technical and socio-economic explanations for, and policies to counter non-evacuation are vital, they are insufficient as they have not been able to encourage 100% of exposed populations to evacuate. A more complete understanding of hurricane evacuation can come from further exploration of endogenous factors; the psychological and cultural paradigms which see risk perception as fundamentally subjective. However it is likely that subjective risk perception does not fully explain risk behaviour; rather risk behaviour is also influenced by social networks as we are social animals living in societies. This area of research has been largely overlooked until recently, but it is likely that with the development of social media, the role of subjective norms and networks will increase in significance.

Chapter 3: The Case Study

3.1 Introduction

This chapter gives a brief account of the location of the study. It covers relevant human and environmental geography of Galveston Island in addition to its hurricane history. It then examines the history of Hurricane Ike, the preparations made in Galveston, and the impact it had on the island. The purpose of the chapter is to introduce some of the characteristics of the island, the hurricane and the response which are important in the design of the methodology and the two empirical chapters.

3.2 The case study location: Galveston

According to Yin (2009), an exemplary case study is likely to be unusual, of general public interest, and of national importance. This can be in theoretical, policy or practical terms. The hurricane and area selected to be studied are Hurricane Ike and Galveston. The following section will demonstrate that this case is certainly of public interest and national importance at both a theoretical and policy level. Firstly, Galveston has been affected by numerous hurricanes since records began in the 19th century as its location and precarious topography make it vulnerable. It is also possible that the threat of hurricanes will increase with climate change (Emanuel et al., 2008). Secondly, Galveston has attempted to control hurricane risk with solutions inspired by technical and socio-economic approaches. The technical approach has been through building the seawall, raising the height of the island and using technology for risk communication. The socio-economic approach has provided evacuation assistance for disadvantaged communities. Thirdly, Hurricane Ike has been understudied compared to other hurricanes. Although not as newsworthy as Hurricane Katrina due to the much lower death count, Ike demands attention because it was so different to Katrina. If the

narrative of Katrina was of African Americans lacking the ability to evacuate, it is probable demographics do not explain the non-evacuation for Hurricane Ike as Galveston has a different demographic characteristics and is not so affected by poverty. This could make Galveston a more demographically representative case study for coastal USA.

Galveston is an island located on the Texan coast on the Gulf of Mexico, 2 miles from the mainland and 50 miles from Houston. Galveston has no bedrock; it is a barrier island formed around 5,000 years ago by the depositing of sand and silt and as a result has a naturally low elevation. One early visitor explained the island's appearance particularly effectively 'it looks like a piece of prairie that had quarrelled with the main land and dissolved partnership' (Sheridan as cited in Pratt, 1954, p. 32). It varies in width from 1.5 to 3 miles and is 27 miles long. Pelican Island lies to the north and provides protection for a port; the main reason Galveston was deemed a suitable settlement. The East End of the island is protected from the Gulf of Mexico by the seawall, while the West End is unprotected (figure 3.2). Behind the island, to the north is Galveston Bay, a large expanse of water, 30 miles by approximately 17 miles which serves as a drainage basin for several streams and rivers. Galveston's location means it is 'exposed directly to wind, tides and the vagaries of a barrier-island environment' (Blazyk, 2000, p. 405). Interstate 45, which runs north-west to Houston is the main route off the island. Galveston does have a bridge south-west to neighbouring Surfside Beach and a ferry route north-east to the Bolivar Peninsular, but these are closed in the event of a hurricane.

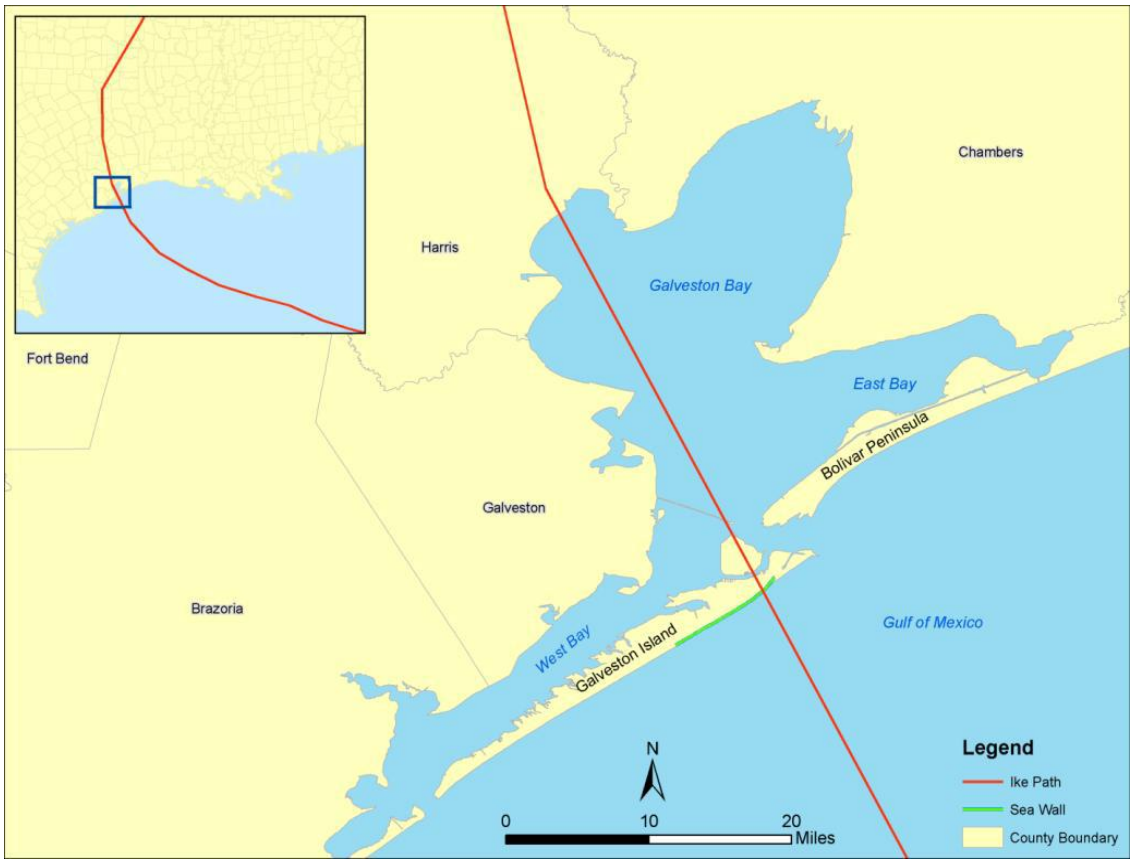

Figure 3.1: Galveston's exposed location and the course of Hurricane Ike. (Peacock et al., 2011).

In 1979 the US Corps of Engineers predicted the damage a large hurricane could do to Galveston if it flooded the island from the bay. A 12.5 mile levee system was proposed which would protect the harbour side of the island. The project would be federally subsidised but also 30% funded by Galveston County. The levee was never built as the Galveston County Commission refused to fund the expense due to public apathy (Wilder et al. 2007). It can be argued that the existing infrastructure of sea defences and development is contributing to increasing the level of exposure of the island. The seawall prevents the natural processes of the barrier island, such as rollover, meaning that the beach against the Seawall is shrinking. At present the beaches of Galveston are eroding due to sea levels rise and the extraction of oil, gas and groundwater causing subsidence (Wilder et al. 2007). As a result, wetlands are being lost at an alarming rate. Nonetheless the West End continues to be a hot spot for development, encouraged by unsustainable beach nourishment (Wilder et al. 2007).

Galveston has been impacted by hurricanes throughout its history. In the 19th century alone Galveston was hit by hurricanes eleven times, although it was able to avoid the fate of neighbouring Indianola which was destroyed in the hurricane of 1886 and subsequently abandoned (McComb, 1986). At the start of the 20th century, Galveston was known as the "Treasure Isle" and with a population of 37,000 it was the fourth biggest city in Texas (Blazyk, 2000), as well as the richest and most cosmopolitan (McComb, 1986). Its new deep water harbour made it the main port for Texas and the most important cotton port in the world. It had a fast developing banking and commerce sector and ambitions to be the New York of the South (Blazyk, 2000). By the start of the twentieth century there was an understanding of the threat posed by severe weather to the island. It had been recorded that Galveston's geography and topography 'render it, in the presence of severe storms, peculiarly subject to inundation' (Garriott, 1900, p. 391). Despite this knowledge, little had been done to improve the physical infrastructure of the island. Beaches were left unprotected, sand dunes 12-15 feet high on the Gulf shore had been removed for development by the end of the 19th century (Davis 2000), and the maximum elevation in the city was eight feet seven inches. The hurricane warning system at this time was rudimentary with vague information in the local newspaper followed by a flag warning residents of the impending landfall (Larson, 1999).

The "Great Storm", a category 4 hurricane which struck Galveston on September 8th 1900 is normally considered the worst natural disaster in US history. According to a local historian and weather expert, due to its life altering impact 'virtually all events in the city's history must be viewed to some extent through the lens of that experience' (Blazyk, 2000, p. 357). Before landfall, a northerly wind over the 35 mile stretch of Galveston Bay pushed water into the city. This meant in effect the island suffered two storm surges – firstly from the bay and later from the Gulf. In fact the northerly wind had kept the Gulf surge at bay making it a 'compressed spring, ready to leap forward the moment the winds shifted' (Larson, 1999, p. 221). Later the wind changed to the east meaning the Gulf surge impacted the East End of the island. When the wind shifted to the South the island was hit by the full force of a storm surge built up over a fetch of 800 miles. The result was a 15-20 foot tide which destroyed 3,600 buildings,

approximately one third of the city. Over 6,000 people were killed by the flood and the tragedy lives on in the collective memory of the people of Galveston, many of whom can tell you of the losses suffered by their family. For this reason the Great Storm is seen as a psychological watershed on the island (Blazyk, 2000).

Despite the deaths and a refusal by some to return, those who remained on the island were determined to ensure a similar tragedy would not be repeated. A massive undertaking raised the height of the city by eight feet, while the other result of the Great Hurricane was the construction of the seawall. Construction started in 1902 and was completed in July 1904. It initially covered 3.3 miles but was extended to over 10 miles by 1963 and stands 17 feet high. The seawall now protects the East End, but not the West End or Galveston Bay. As such, it can be argued that a technical approach appeared to prevail as the island continued to be inhabited thanks to the engineering of sea defences (McComb, 1986). Although Galveston was soon superseded by Houston as a port and industrial centre, it survived as a viable city, albeit a less dynamic and optimistic one.

Galveston was impacted by twenty-three hurricanes and fourteen tropical storms during the twentieth century alone. Since the Great Storm other significant hurricanes have occurred approximately every 20-25 years. Another category 4 hurricane arrived in August 1915. It would have probably devastated the city had the seawall not been in place, as it was over 50 residents were killed. In addition to the seawall, a warning system was developed to reduce the human impact of the hurricane. This involved firing rockets into the sky at half hourly intervals, the use of telephone messages and motor cycle messengers (Blazyk, 2000). The hurricane which occurred in July 1943 was proof that a hurricane impacting Galveston does not need to have major status in order to be destructive and dangerous. Like Ike, it was a category 2 hurricane at the time of landfall. Due to wartime restrictions on weather reporting, residents were given little time to prepare for the impact. Although there was in some parts several feet of flooding, water was less of a danger than wind. No residents were killed on the island, but there were 19 marine deaths. The hurricane was noteworthy for the world's first air reconnaissance flight into the storm (Blazyk, 2000).

Hurricane Carla which took place in September 1961 was the hurricane which defined the city in the second half of the twentieth century. It was also one of the first hurricanes experienced as a media event and triggered the first mass evacuation of the island. As the anticipated hurricane slowly made its way towards the island, an estimated 50,000 people left Galveston, with approximately 15,000 remaining to weather the storm. Even though this category 4 hurricane made landfall over one hundred miles away, it caused several tornados on Galveston which took the lives of 6 residents. The last major hurricane to impact Galveston before Ike was Alicia which made landfall as a category 3 in August 1983. The fact that only 6,000 residents evacuated may be explained by the rapid movement of the hurricane and the unnecessary evacuation from Hurricane Allen three years previously (Blazyk, 2000). Although there were no fatalities, the havoc caused by the high winds led to criticism of the mayor for not calling an evacuation.

One final hurricane which had a significant impact on Galveston is Hurricane Rita. However, the importance of Rita is not that it hit the island, but the opposite; Galveston was left unscathed. Rita was forecast to make impact as a category 5 hurricane near Galveston in September 2005, before changing course and losing intensity at the last minute and making landfall as a category 3 hurricane at Sabine Pass, 40 miles from Galveston. As Hurricane Katrina had recently impacted Louisiana, a panicked and ultimately unnecessary evacuation occurred. It is likely that this “crying wolf” (Dow and Cutter, 1998) made some Galvestonian residents unwilling to evacuate in the future.

Ten major hurricanes have made landfall in Texas since 1950 and in any one year Galveston has a 1 in 25 chance of being impacted by a hurricane and a 1 in 60 chance of being impacted by a major (category 3 or above) hurricane (Nolen et al., 2010). It may be tempting to see Ike as an anomaly as it reflected 100 year surge levels, but it is possible that the intensity of hurricanes in the Gulf could increase (Holland & Bruyère 2013). The Galveston Seawall has never been tested by a category 5 hurricane, which might be more likely in the future (IPCC 2012). Higher intensity hurricanes and storm

surges will be compounded by predicted sea level rises (Dasgupta, 2009; Frazier et al., 2010). This could mean a one metre rise in sea level would enable a 15 year hurricane to inundate land only currently flooded by 100 year storms (Kana et al., 1984). Research on Galveston suggests by 2100 water level exceedance probabilities will double for the largest hurricanes such as Hurricane Ike and increase by six times for smaller storms (Warner and Tissot, 2012). Climate change is not the only anthropogenic impact on the environment which could augment the effect of hurricanes in the Mexican Gulf. The 2010 BP oil spill off the Louisiana Coast demonstrated another risk, with the oil killing protective wetlands and the potential for a hurricane pushing an “oil surge” inland (Trevors and Saier 2010).

Contemporary hurricane evacuation policy for the City of Galveston is based on three pillars; the evacuation order, the evacuation plan and the Citizen Response Team. The City of Galveston emergency services begin to make preparations when a hurricane is 120 hours from impacting the coast. They undertake conference calls with the National Weather service and the Governor twice a day. A voluntary evacuation is normally called 72 hours before tropical storm force winds (over 39 miles per hour) impact. For the West End the evacuation order is made earlier, as the low elevation and lack of sea defences mean roads can get flooded suddenly. As a result, evacuations are sometimes called for tropical storms and category 1 hurricanes. A mandatory evacuation is normally called 48 hours before impacting tropical force winds (Kelly, 2010).

Evacuation from Galveston can be problematic. Residents fear the possibility of gridlock as tens of thousands of residents from Galveston, Brazoria and Chambers counties all attempt to escape through the Houston metropolitan area. To ensure a safer, more efficient evacuation of the Galveston-Houston area, local counties have recently adopted a zip code evacuation plan. The zip codes correspond to storm surge risk areas and were chosen as the easiest way to communicate evacuation information. The City of Galveston plans to be evacuated 24 hours before the storm makes landfall in order to give other cities, especially Houston the time to then evacuate (Litman, 2006).

The City uses the “One Call Reaches All – Emergency Notification System” which sends messages simultaneously through voice and text formats to landlines, mobiles and email. Those who need help evacuating for economic or medical reasons can register with the Citizens Response Team and in the event of a storm they are contacted and offered assistance. The City collects a list of residents requiring assistance in the days and months leading up to hurricane season (Kelly, 2010). After a mandatory evacuation is ordered, residents requiring assistance are told to meet at the Community Centre in central Galveston, where they are met by buses to take them to a shelter in Austin. Since Ike, residents evacuated by the City will wear electronic wristbands for tracking and to manage their re-entry onto the island.

Two assumptions underlie the Galveston evacuation strategy. The first is that when informed of the risk and when given a mandatory evacuation order, car owning residents will evacuate independently and at the correct time according to the evacuation zip zones. The second assumption is that those without access to a car or unable to evacuate independently will have registered with the Citizens Response Team and be willing to evacuate when deemed necessary by the City. Therefore we can see that the evacuation plan for the City of Galveston is based on a limited interpretation of risk perception. A reliance on the evacuation order is derived from the technical approach. The use of the Citizens Response Team is a solution from the socio-economic paradigm, but is also dependent on the technical understanding of risk as residents must register if they believe they are in need of assistance and also meet at the Community Centre to evacuate.

Galveston has a multi-ethnic population as recorded by the 2000 census; the last census before Hurricane Ike (US Census Bureau, 2000). As Galveston is a port, it has always had a wide variety of peoples since the first European settlement was established in 1816. According to one local historian, the ensuing ‘flow of immigrants through this Texas gateway provided cultural heterogeneity’ in the decades which followed (McComb, 1986, p. 105). In the 19th century Galveston was also a sometime centre for the sale of slaves, and after the Civil War many African Americans settled in Saccarap, on the Bay side of the East End (McComb, 1986). More recently there have

been inflows of Hispanics. The 2000 census recorded a population of 57,247 comprised of 44.2% Caucasians, 26% African Americans and 25.8% Hispanics in addition to small Vietnamese and Amerindian populations (US Census Bureau, 2000). Galveston is urbanised, although settlements are not uniform with 89% of the population living on the East End in the City of Galveston. There are many second and holiday homes situated in the West End. The population density of Galveston was 1,240.4 people per square mile (US Census Bureau, 2000) and there were 23,842 households with a median income of $28,895. The proportion of the population below the poverty line (defined as a family of four with an annual income below $22,314) was 22.3%. Since Hurricane Ike, the population has dropped to 47,743 (US Census Bureau, 2010).

Much hurricane evacuation research for the Gulf has been carried out in New Orleans using Hurricane Katrina as a case study. Galveston is more representative of the US Gulf Coast ethnically and socio-economically than New Orleans, with its majority of African American residents and higher levels of poverty (table 3.1). If socio-economic and ethnic factors have been used to explain Hurricane Katrina, then it might be difficult to argue the same for Galveston, with its lower African American population and less underserved communities. Therefore a study of Ike could be important in revealing other factors involved in the evacuation decision making process. The topography of Galveston, while coastal, low lying and therefore threatened by meteorological events, does not have the extreme level of exposure characterised by New Orleans, which is located below sea level between the Mississippi River and Lake Pontchartrain. Galveston is more representative of the barrier islands which line 3700 km of the Atlantic and Gulf Coasts and are home to 1.4 million people (Zhang and Leatherman, 2011). In Texas alone there are 10 barrier islands which line 591 km of the coast, the longest barrier shoreline after Florida (Zhang and Leatherman, 2011). The human and physical geography of Galveston could mean that some findings might be applicable across the Gulf of Mexico and the Atlantic Coast.

Table 3.1: A comparison between the cities of Galveston and New Orleans for 2010

	Galveston	New Orleans
Population 2010	47,743	343,829
Percent White	45%	30.35%
Percent African American	19.2%	60.2%
Percent Hispanic	31%	5.2%
Percent below poverty line	22.6%	25.7%
No access to vehicle	13.5%	18.4%
Households lacking plumbing, kitchen or telephone facilities	5.3%	10.4%

Adapted from US Census Bureau (2010).

3.3 The history of Hurricane Ike

Hurricane Ike, the ninth and most intense storm of the 2008 Atlantic hurricane season, formed off Cape Verde at the start of September 2008. By September 4th it was a category 4 hurricane with maximum sustained wind speeds of 145 mph which it maintained as it passed over the Turks and Caicos Islands. It made two landfalls on Cuba; the first as a category 4 at Cabo Lucrecia on September 8th and the second at Pinar del Rio on September 9th before entering the Gulf of Mexico (Berg, 2009). Although Ike did not make landfall on Hispaniola, it deposited a great deal of rain on Haiti causing 74 deaths. Forecasting the intensity and location of Ike's landfall on the USA was particularly complex due to its rapid intensification, multiple landfalls and anomalous behaviour over the Gulf of Mexico (Berg, 2009). Ike eventually made landfall at the East End of Galveston at 03:00 on the 13th September 2008 (figure 4.1). At the time of impact, it had decreased from a category 4 to a category 2 hurricane, but still buffeted Galveston with winds of 110 mph (Berg, 2009). It then moved north-west and north before losing energy and becoming an extra-tropical storm.

Figure 3.2: The path of Hurricane Ike. (FEMA, 2009).

3.4 Preparations for Hurricane Ike

Because of the unpredictable behaviour and erratic course of the hurricane (FEMA, 2010), evacuation orders for the island of Galveston were not made according to standard procedure (table 3.2). According to the City Emergency Manager, 'on Ike we were about a day behind' the desired schedule as on the morning of the 10th of September, the worst of Ike was initially forecast to miss Galveston (Kelly, 2010). A mandatory evacuation order was issued for the whole island at a press conference at 9.30 am on the 11th September (Rice, 2008). This meant the mandatory order was made approximately 30 hours before tropical storm force winds impacted Galveston, as opposed to the standard 48 hours and approximately 40 hours before landfall. Also on the 11th, a release from the National Weather Service warned the public that 'persons not heeding evacuation orders in single family one- or two-storey homes will face certain death' (National Weather Service, 2008). By the afternoon of the 12th, waves from the storm surge were overtopping the seawall and low lying areas were flooded from water coming in from Galveston Bay, making evacuation impossible

(McKinley Jr and Grynbaum, 2008). By the evening of the 12th, still several hours before the hurricane made landfall, tides were already up to 8 feet above normal levels in the vicinity of Galveston (Berg, 2009).

Table 3.2: The course of Hurricane Ike and the policy response

Event	Date and approximate time
Ike passes over Cuba and enters the Gulf	9th September 14:00
Ike forecast to miss Galveston	10th September 09:00
Mandatory evacuation order issued	11th September 09:30
"Certain death" statement issued	11th September 20:00
Overtopping of seawall	12th September 15:00
End of pre-landfall rescue efforts	12th September 21:00
Landfall on Galveston	13th September 03:00

The City used the "One Call Reaches All – Emergency Notification System" and Citizens Response Team which had collected a list of residents requiring assistance in the days and months leading up to hurricane season. For the 2008 hurricane season there were under 500 residents on the list, but in the event almost 2000 required help to evacuate from Ike (Kelly, 2010). This suggests that the publicity campaign asking residents to register was only relatively successful, or that people had an unrealistic perception of their ability to self-evacuate. After the mandatory evacuation was ordered, residents requiring assistance to evacuate were told to meet at the Community Centre in central Galveston. The city also recognised the needs of pet owners requiring assistance by providing transport for people with their animals. The mayor had negotiated pre-conditioned contracts with the City of Austin to host evacuated people, and supply buses for the evacuation, food supplies and medical care for 4,000 citizens (Thomas, 2013).

In an interview 5 years after Hurricane Ike, the mayor at the time explained the political difficulties in timing the evacuation order 'had we called the evacuation too soon and Ike didn't come, I would have been criticised for that' (Thomas, 2013). The Mayor highlighted the limits of political power in the United States as 'when there's a mandatory evacuation called in Cuba, the Cuban Government sends trucks into the neighbourhoods and takes them somewhere, whether they want to go or not', while in the United States 'whether or not a citizen chooses to leave is that citizen's decision'

(Thomas, 2013). Mandatory evacuation has been the de facto law since 2006. The police can arrest non evacuators in theory, although in reality they do not have the political will to do so, the manpower to drag people out of their houses, or the space to imprison them. Therefore the strategy adopted is to inform the public that after a certain time, the City will not jeopardise the safety of first responders. During Ike this cut-off point was on the evening of Friday 12th September. Nonetheless, on the night of landfall, the City received over 100 calls from residents needing assistance or rescue from their homes (McKinley Jr. and Urbina, 2008). Those staying were encouraged to inform the City of where they would be so the emergency services could check on them after the hurricane. They were also told to write their social security number on their arms for identification. There was an agreement with the school district to provide a shelter of last resort, although this was not widely publicised in order to discourage people from staying. In the event, about 500 people sought refuge at Ball High School (Kelly, 2010).

3.5 The impact of Hurricane Ike

The storm surge for Hurricane Ike was much higher and earlier than typical for a category 2 hurricane. The impact of the storm surge for Ike can be explained through three factors; the forerunner surge, the size of the wind field and the bathymetry of the coastal area. Ahead of the storm surge, Galveston was subjected to a forerunner surge. This meant that a wave travelled up to 300km ahead of the hurricane and arrived 12-24 hours ahead of landfall (Kennedy et al., 2011). This was unpredicted and led to inundation taking place earlier than expected, and intensification of flooding when the main storm surge arrived (Kennedy et al., 2011). The forerunner surge, combined with the relatively late mandatory evacuation order meant that there was only a little over a day between the issuance of the mandatory evacuation order and the start of flooding. The wind field, or width of the hurricane also contributed to its impact. As the hurricane measured 200km across, an unusually large volume of water was funnelled into the Gulf of Mexico, concentrated on and around Galveston Bay. The bathymetry of the coastal zone of Galveston also exaggerated the impact of the storm surge, due to the shallow water.

Hurricane Ike made landfall on Galveston, with the eye of the storm passing directly over the East End of the island (figure 4.2). It could be argued that Galveston was fortunate not to have been affected more. It made impact as a category 2 hurricane, although some models expected it to impact as a category 3, which could have brought an even bigger surge. Moreover, if the course of the hurricane had been slightly to the West, the more dangerous “dirty” side of the hurricane, which tends to be characterised by stronger winds and a higher storm surge, would have directly impacted the City of Galveston. Neighbouring Bolivar Island felt the full force of the dirty side and was totally inundated. There was a large discrepancy between the height of the storm surge from Ike and the usual height of a storm surge from a category 2 hurricane as according to the Saffir-Simpson scale a category 2 hurricane normally brings a surge of 6-8 feet (Simpson and Saffir, 1974). On Galveston the high water mark was 13.5 feet on the bay side, the result of water entering the bay and being forced up back over the island, while the southern urban centre of the City of Galveston was protected by the seawall. Seventy five percent of the island was flooded and approximately the same proportion of residents were displaced after the hurricane. Some of the buildings were submerged up to 13 feet in polluted water and many historic buildings were destroyed and businesses affected. The University of Texas Medical Branch was flooded, resulting in $700m worth of damage (FEMA, 2010). Total damage from Hurricane Ike amounted to over $25 billion, including substantial damage to the Gulf oil industry, making it the third costliest hurricane in US history (Berg, 2009).

Figure 3.3: The landfall of Hurricane Ike on Galveston (the diagonal line shows the course of Hurricane Ike). (US Geological Service, 2012).

3.6 Studies on evacuation from hurricane Ike

Estimates vary about how many residents evacuated from the island. At the time of the hurricane, most newspapers and networks estimated that between 70-80% evacuated, although some estimated this figure was as low as 60% (McKinley Jr. and Urbina, 2008). The Hurricane Ike Post Storm Assessment claims 85% evacuated, although it is to be noted that this is also based on an estimate (FEMA, 2010). There is one large unpublished survey of evacuation numbers from Galveston (Van Zandt, 2010). This random sample of single family homes generated an overall evacuation rate from Galveston Island of approximately 80%, although this did not include multi-family housing units. They found households with no vehicles, single parents, renters, females, low income and non-whites were less likely to evacuate. They also found transport dependent populations evacuated later, and ethnic minority neighbourhoods were more severely damaged. This wide-ranging survey is more

focused on post-hurricane recovery and as such lacks depth on how the decision to evacuate was made.

To the author's knowledge, there has only been one published study which focuses on the evacuation decision making of Galveston residents due to Hurricane Ike (Morss and Hayden, 2010). This is a qualitative study consisting of semi-structured interviews which took place approximately 5 weeks after the impact of Hurricane Ike. Forty-nine interviews were conducted, but only 41 of these were with residents of Galveston Island, the rest from nearby Kemah. Of the 49 participants, 44 were resident in Galveston County at the time of the hurricane. Thirty four of these evacuated (77%). Residents who left explained that their decision was triggered by the evacuation order, concern about their safety and the necessity to evacuate family members. However, the authors noted it was problematic to discretely define how evacuation decisions are made as they… 'evolve over time, as the threat, the situation, and people's understanding of them evolve' (Morss and Hayden, 2010, p. 187). Of the non-evacuators, the reasons given for staying were they felt safe in their residence as it was elevated or protected, they had confidence in the seawall or were put off by the negative aspects of evacuating such as traffic, financial problems and family constraints. On the whole, participants claimed they relied on their own judgement more than that of the authorities or family and friends. The statement issued by the National Weather Service (2008) warning those who remained on the island faced certain death was also investigated, with 70% of participants aware of it at the time. It was seen as divisive with half of the population describing it positively as effective, while the other half saw the statement as negative, terming it overblown. The majority of participants said it did not impact their decision to evacuate. Of the 10 whose decision was affected, 8 said it contributed to the decision to leave while 2 said it reinforced their decision to stay (Morss and Hayden, 2010).

In addition to the studies on Galveston there have been some studies which have investigated the evacuation of Houston residents from Ike. A survey by the Houston Chronicle found that 42% of evacuators from Houston left mainly because they did not want to go without electricity (Berger, 2008). Another study found that undocumented

workers were often unwilling to evacuate as they were worried that they would be arrested and Spanish language television presented the risk in a very different manner to the English language television channels (Tiefenbacher and Wilson, 2012). They also found that financial constraints and a lack of gasoline and shelter prevented evacuation for a large section of the undocumented community. A different survey of Houston area residents found socio-economic factors did not determine informational needs, but ethnicity and gender did (Spence et al., 2011).

It was also found that in mandatory evacuation zones in Texas, people more committed to their pets had lower probabilities of evacuation (Brackenridge et al., 2012). Another study suggested that an unnecessary or "shadow" evacuation resulted due to lack of agreement between subjective risk perception and risk assessment on the part of policy makers, therefore lack of information might be to blame (Stein et al., 2010). There have been attempts to model evacuation from Hurricane Ike, although these focus on traffic flows (Huang et al., 2012). There are, to the author's knowledge, no published studies which attempt to model the impact of social networks on the evacuation decision making process for Hurricane Ike.

Research on mortality found that there were 74 deaths in Texas which could be attributed to Hurricane Ike. Ten deaths can be attributed directly to Ike through drowning and being hit by tree limbs. Forty-nine are attributed to indirect causes such as carbon monoxide exposure and cardiovascular failure. Fifteen deaths are possibly attributed to Ike through mainly unknown injuries and illnesses (Zane et al., 2011). Seventeen of the deaths occurred in Galveston County (Zane et al., 2011), while others remain officially missing (Berg, 2009). Those that survived the hurricane by sheltering at home or elsewhere on Galveston had appalling conditions to contend with (McKinley Jr, 2008). Without water, power, fresh food or a functioning sewerage system non evacuators were at risk of extreme discomfort and disease. No hospitals were open and there were only four ambulances serving the island, one of which caught fire. There was insufficient manpower and medication to treat seizures, chest pains and dehydration (Urbina, 2008). Studies made since the hurricane have highlighted the impact of non-evacuation on the psychological health of Galvestonians.

One study found that residents affected by the hurricane were more likely to be affected by Ike-related Post Traumatic Stress Disorder (Tracy et al., 2011). A further study has highlighted the links between non-evacuation and psychological well-being of Galvestonian adolescents (Temple et al., 2011). It found high school students who did not evacuate were more likely to perpetrate and be victims of sexual assault and reported more alcohol and drug abuse than non-evacuators.

Galveston and Hurricane Ike make an ideal case study for answering research questions on hurricane evacuation behaviour due to the island's exposed location, evacuation policies and representativeness as Gulf Coast settlement. Moreover, the relative lack of studies on Hurricane Ike and Galveston make it a practical case study. There are also methodological considerations as to why it makes an ideal case study. A hurricane recovery survey had been undertaken before the fieldwork for this thesis was undertaken (Van Zandt 2010). This gave raw data of evacuation decision and timing for over 400 residents of Galveston Island. The data is useful for triangulation with the Q study and for parameterising the ABM. In addition, Galveston Island's small size and status as an island makes modelling the social networks more simple than a larger, or more geographically diverse area.

3.7 Conclusion

This chapter has given a brief account of Galveston, the course of Hurricane Ike, the preparations made before landfall in Galveston and the impact of the hurricane on the island. Complexities in the hurricane history of Hurricane Ike had implications for the evacuation of Galveston Island. As the hurricane was constantly changing course, the mandatory evacuation was called late. Due to the size of the hurricane, the height of the storm surge was larger than normally expected for a hurricane of Ike's category, while the forerunner surge meant that rising water arrived earlier than expected. These characteristics of the hurricane and the policy response have implications for the design of the empirical research methods. The following chapter discusses the utility of the case study approach and introduces the research methods to be used in the study.

Chapter 4: The Methodology

4.1 Introduction

This chapter explains the methodology which will be used throughout the thesis. It begins by restating the research questions and introduces the methodological framework which will be used to answer them. The chapter then introduces a discussion of the case study and mixed methods approach, which is the methodological approach adopted to test the research questions. Finally the two methods to be used in the empirical chapters of the thesis are introduced; a Q study which is used to unveil subjective attitudes around hurricane evacuation and an agent based model (ABM) which is used to simulate the impact of subjective norms and social networks on hurricane evacuation. The two tools are integrated as the ABM investigates societal-level hurricane evacuation by simulating the impact of shared subjective attitudes (as revealed by the Q study) as they interact through subjective norms and networks. This chapter is solely concerned with the methodological aspects of the thesis. Details on the application of the methods are in the empirical chapters which follow.

Figure 4.1 depicts the mixed methods the thesis adopts to address the framework and give an original insight into the problem of hurricane evacuation. The theory of decision making to be used is the TRA (Fishbein and Ajzen, 1975), adapted to include insights from Roger et al. (1983) and Sheeran et al. (2013). The determinants of subjective evacuation attitude are underlying beliefs, threat appraisal and risk appraisal and these are to be investigated with the Q study. The prevalence of different subjective evacuation attitudes on the island as a whole is to be based on the findings of the Van Zandt (2010) survey.

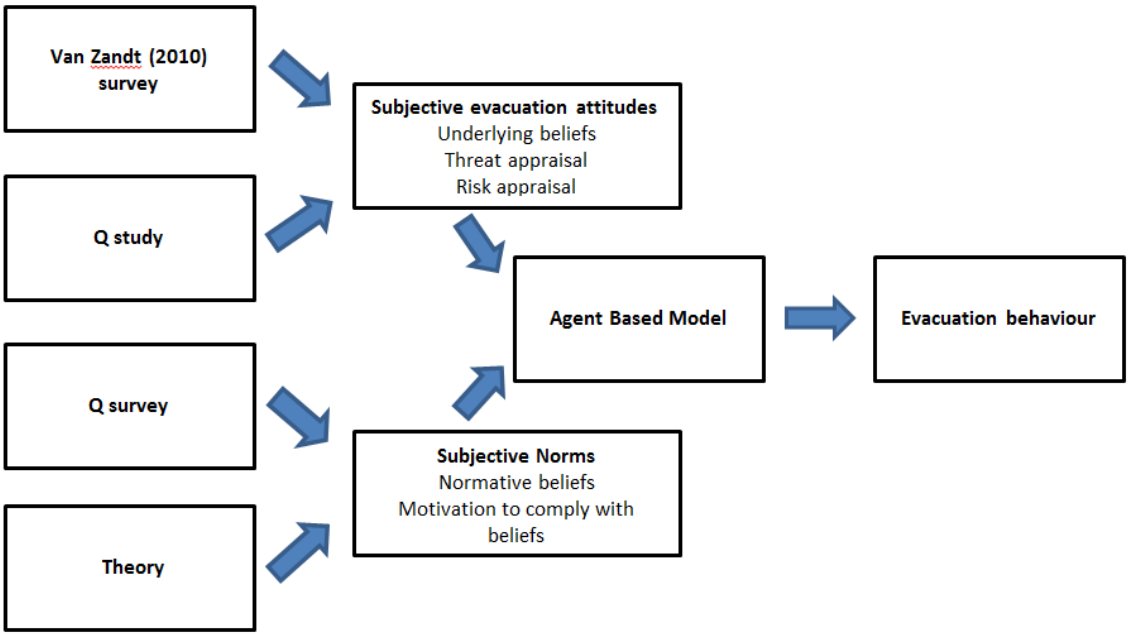

Figure 4.1: The mixed methods and framework of the thesis. Adapted from Fishbein and Ajzen (1975), Rogers et al. (1983) and Sheeran et al. (2013).

In this way it is possible to answer the first research question:

1. How do subjective evacuation attitudes affect hurricane evacuation decisions?

According to the TRA, evacuation intentions are formed through subjective evacuation attitudes, which might then be altered by subjective norms which are communicated through social networks (Fishbein and Ajzen, 1975). Subjective norms concerning evacuation are understood as normative beliefs concerning evacuation and the motivation to comply with these beliefs. The impact of subjective norms comes from the survey which was undertaken at the same time as the Q study. This revealed the extent to which the participants believe that they were influenced by the members of their social network. However, as people often do not know the extent to which they are influenced by others (Christensen and Ruch 1980), it was decided to also use theory to investigate subjective norms. As such, literature on the size and type of social network was also utilised. The ABM uses subjective evacuation attitudes and subjective norms to answer the remaining research questions:

2.a. How do different subjective evacuation attitudes combine with subjective norms to create large scale patterns in hurricane evacuation?

2.b. How might changes in subjective evacuation attitudes, subjective norms and social networks alter large scale patterns in hurricane evacuation decisions?

Although the two main methods to be used in the thesis, Q and ABM, are rather different from an epistemological point of view, they share a focus on subjectivity. The Q study focuses on the subjective attitudes of the participants, while the agents of an ABM are able to adopt these attitudes as rules of behaviour and interact with each other communicating subjective norms. Such integration has great promise for the understanding of society-level risk behaviour and methodological development alike, as to the author's knowledge a Q study and an ABM have not been integrated before.

4.2. A case study approach

In order to investigate the way in which individual decisions are taken and the impact that these decisions might have on societal evacuation behaviour, it was decided to take a case study approach. According to Yin (2009, p. 18) 'a case study is an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident'. A more general definition stresses the importance of the case study in making a contribution to policy as 'the central tendency among all types of case study, is that it tries to illuminate a decision or a set of decisions: why they were taken, how they were implemented, and with what result' (Schramm, 1971, p. 6).

Flyvberg (2006) supports the use of the case study, claiming that deep knowledge requires a nuanced understanding beyond that of general rules which cannot fully explain a complex research matter such as a society. In this way, context dependent knowledge can be viewed as even more valuable than context independent, theoretical knowledge. It is true that case studies, unlike studies with larger samples, are unable to produce statistically significant results. However, according to Yin (2009)

what determines the generalisabilty of a study is not the size of the sample or the number of replications of an experiment but the rigour with which the case is selected, and the method applied. Moreover, even if knowledge cannot be generalised, that does not mean that it cannot contribute to knowledge accumulation (Flyvbjerg, 2006). Detailed empirical analysis is therefore of great value to practitioners and theorists alike. It has also been claimed that the case study is often based on qualitative methods which are liable to bias, meaning the findings might only reaffirm the preconceptions of the researcher (Miles and Huberman, 1994). It is true tools used for case study research can permit the intrusion of researcher subjectivity, but again according to Flyvberg (2006) this is only the case when methods are not applied sufficiently rigorously. In fact a degree of flexibility in the research could be viewed as positive as it allows a researcher to take advantage of emerging themes (Eisenhardt, 1989).

4.3 A mixed methods approach

This thesis is a mixed methods study as it combines qualitative and quantitative research. Purists of each side have tended to resist the other paradigm through the incompatibility thesis (Howe, 1988), which claims quantitative and qualitative research and their methods should not be mixed. As Guba states 'accommodation between paradigms is impossible…we are led to vastly diverse, disparate, and totally antithetical ends' (Guba, 1990, p. 81). Recently scholars have attempted to reconcile the two research methods into a third research paradigm which has evolved from a dissatisfaction with this division of the two codes into binary opposition and a need for epistemological and methodological pluralism or pragmatism. Mixed methods are defined as 'the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study' (Johnson and Onwuegbuzie, 2004, p. 17). Assuming they are appropriate to the research questions, mixed methods can be practical, complementary and can enable communication across paradigms (Maxcy, 2003). In terms of case study research, data can be qualitative, quantitative or both (Yin, 2009) and the combination of data types can be highly synergistic (Eisenhardt, 1989). This

thesis adopts this position, as a combination of qualitative and quantitative methods is an appropriate way to explore how subjective evacuation attitudes and subjective norms communicated through social networks can combine to enable the understanding of evacuation behaviour.

4.4 Q method

The first research question is:

1. How do subjective evacuation attitudes affect hurricane evacuation decisions?

In order to answer this question it was necessary to select a method which facilitates the investigation of subjective attitudes. Converse (2006) has highlighted the problem of attempting to gain an understanding of individual subjectivity: 'belief systems have never surrendered easily to empirical study or quantification. Indeed, they have often served as primary exhibits for the doctrine that what is important to study cannot be measured and that which can be measured is not important to study' (Converse, 2006, p. 206). It has also been argued that traditional quantitative methods such as surveys are unsuited to revealing subjectivities, lead to uncontextualised analysis and a loss of meaning (Mrtek et al., 1996).

Q method is a tool which was created to get to grips with individual subjectivity, or people's perspectives on a given issue (Stephenson, 1953). It has been described as 'appropriate to questions about personal experience… and matters of taste, values and beliefs' (Baker, 2006, p. 2343). The primary aim of Q method is to 'map out the field into groups of persons who resemble one another with respect to whole aspects of their personality' (Stephenson, 1936, p. 278). It works by identifying shared viewpoints (known as factors) over contested topics and statistically measuring participants' affinity to these views. It is a participative and reflexive tool (Ockwell, 2008) which minimises bias and produces valid results from a small sample (Brown, 1980). Q is a qualitative and quantitative social constructivist research tool technique, and

abductive as it can be used to study facts and devise a theory to explain them (Watts and Stenner, 2012).

Eden et al. (2005) have identified within Human Geography a move in recent years from quantitative towards qualitative methods, with focus groups and in depth interviews becoming more popular than surveys. However, in the same article they also claim that in funding and policy circles there remains a preference for quantitative methods. They argue that Q method is able to embrace and balance both these considerations as it uses factor analysis, yet subjectivity is also central. This means Q enables flexibility and creativity on the behalf of the researcher, engages interviewees and produces meaningful, quantitative results from a small number of participants (Eden et al., 2005). In a recent article Wright (2013) concurs that Q gives structure to the analysis of qualitative data as the interpretation is not driven by the researcher's reading of the data, but by statistics. Consequently it can be argued through the use of Q, Geography can overcome some of its "physics envy" by incorporating some of the robustness of quantitative data typical in the natural sciences (Massey, 1999). Robbins and Krueger (2000) have questioned the objectivity of the researcher and the lack of bias in the method. Eden et al. consider these potential weaknesses but conclude Q is an appropriate method for Human Geography:

> …with the caveat that it is employed reflexively and creatively, with full awareness of its interpretive dimensions and not as a number crunching exercise. The subjectivity of the researcher is therefore to be valued rather than elided and novelty can be an aid to reflection.
> (Eden et al., 2005, p. 421).

Literature is growing on the use of Q in revealing how decisions are made. It has been used to explain how beliefs and values contribute to decision making in areas as diverse as medical ethics (Wong et al., 2004), adaption to health care informatics (Valenta and Wigger, 1997), supply management (Carter et al., 2007) and venture capital (Babcock-Lumish, 2005). There are also works which use Q to unveil rationality. Areas include rationality in voting (Brown, 1980), waste management planning

(Wolsink, 2004), health related lifestyle choices (Baker 2006) and motivation for using a car (Steg et al., 2001). There is a parallel growing literature which uses Q to give a richer understanding of social-environmental interactions, with studies on nuclear power (Venables et al., 2009), bushfire (Ockwell, 2008; Danielson, 2009), flooding (Raadgever et al., 2008) and climate change (Niemeyer et al., 2005; Wolf et al., 2009). To the author's knowledge, Q method has not been used to understand hurricane evacuation before, but the fact it has been successfully employed to understand decisions and in the environmental sciences suggests it is a suitable method.

For a Q study to be effective, initially each possible perspective on the issue at hand needs to be collected and collated into a "concourse" (Webler et al., 2009). This could be in the form of images, but normally takes the form of statements. In order to produce the concourse, it is necessary to sample the most appropriate sources. If the research question is related to academic perspectives on an issue, then academic literature needs to be sampled. If the research question is more concerned with public perspectives on an issue it would be more appropriate to sample popular texts, or to arrange focus groups to generate some appropriate statements. A thorough search is conducted and terminated only when new opinions and discourses cannot be found; when a saturation point is reached (Glaser and Strauss, 1967). All statements used to create the concourse are initially taken verbatim in order to preserve the natural language and to minimise researcher bias (Webler et al., 2009).

The next stage is the creation of the "Q set"; the sample of statements from the concourse to be used in the study. This sampling can be done in a structured or unstructured manner (Brown, 1980). A structured sample requires the concourse to be divided into several themes, according to theory or observation (Watts and Stenner, 2012). The number of statements in a Q set tends to be in the range of 40 to 80, although it has been claimed that these are only rules of thumb and it is possible to generate meaningful results from a Q set of 25 (Watts and Stenner, 2005). A balance is needed when selecting the number of statements; too few and there is a risk of not covering the range of perspectives on a subject; too many and the task of the participant can be daunting and tedious. Statements need to be kept simple and

should address only one proposition (Watts and Stenner, 2012), however some excess meaning or ambiguity within each individual statement is to be encouraged as it enables participants to produce their own meanings through the sorting process (Brown, 1980). The Q set must be balanced, in that it avoids bias towards a particular perspective and if representativeness and balance are achieved then the participant is more likely to be able to express himself. A pruning and fine tuning of the Q set can be brought about through a pilot study. This is an invaluable process which can involve rewording any confusing statements, eliminating duplication and producing new items for the Q set.

In a Q study, the Q set is the study sample, while the participants or "P set" are the variables, for this reason it is unnecessary to use a large number of participants as in a survey (Stephenson, 1936). Q studies can be carried out on one person, but most use at least a dozen so that several of the participants can be identified with each of the factors revealed (Webler et al., 2009). Studies of multiple participants tend to use between 40 and 60 participants, although studies have been performed with many less (Brown, 1980). A Q study uses too few participants to be able to claim generalisability to the wider population (Brown, 1980), although it is possible to use a survey to test findings from a Q Study (Danielson, 2009). Nonetheless, interviewing a cross-section of people increases the likelihood that most of the shared subjectivities present in a society are identified. For this reason it is good practice to select heterogeneous groups, representing different socio-demographic strata and people likely to express a full range of opinions on the issue at hand (Watts and Stenner, 2012).

The participants in a Q study are asked to rank a set of items from a subjective perspective according to their psychological significance (Burt and Stephenson, 1939). This is done through placing statements onto a normal distribution shaped grid usually labelled from strongly agree through zero to strongly disagree (figure 4.2). There is some debate as to whether it is better to use a fixed or free distribution for the shape of the grid used in the sorting process. On the one hand it can be argued that a forced distribution might be constraining for the participant as it limits how they can express their subjectivity (Watts and Stenner, 2012). On the other hand it seems reasonable to

assume that a person feels strongly about a reasonably small number of ideas connected to an issue. For this reason it is claimed that trait measurement normally results in a distribution fitting a normal shaped curve (Burt and Stephenson, 1939). From a more practical point of view, a fixed distribution is a convenient way of facilitating both the ranking process for participants and the analysis and interpretation for the researcher (Watts and Stenner, 2012).

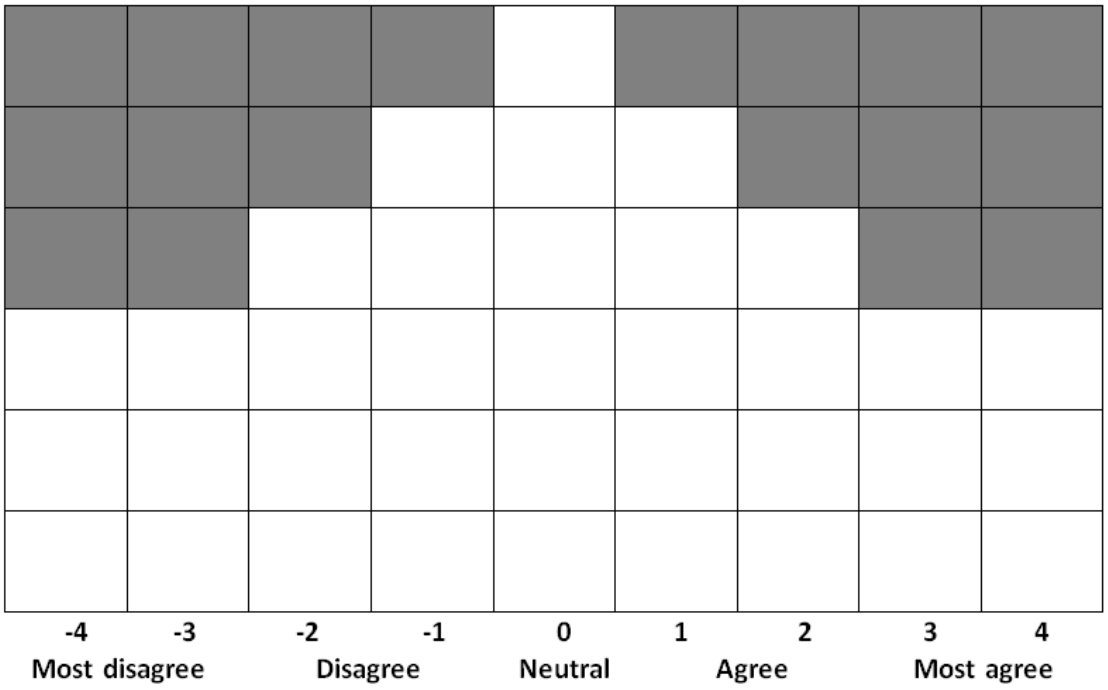

Figure 4.2: A Q sort grid. Source: author

The participants are asked to think aloud whilst undertaking the sorting process so their thought process can be documented by the researcher. After the sort is completed the participants are asked to explain some of their choices to produce context for analysis. This is useful because as one researcher put it, 'we uncover all kinds of relationships in our hard data, but it is only through the use of…soft data that we are able to explain them' (Mintzberg, 1979, p. 587).

In the final stage, factor analysis is used to reveal groups of participants who ranked the items in the Q sort similarly, each factor identifying a group with similar perspectives about a topic (Watts and Stenner, 2012). Specific software is available for this task. Choosing the number of factors to be used for the analysis and subsequent

interpretation is rather subjective. The most common method is to exclude factors with low Eigenvalues (Guttman, 1954; Kaiser, 1960). Another method is Humphrey's rule which states that the product of the two highest loadings should exceed twice the standard error (Brown, 1980). Brown (1980) also states that each factor should be characterised by at least two significant loadings. Each of these mathematical methods for deciding the number of factors can be considered, but the final decision should not be made without considering whether the factors make sense as distinct subjective understandings (Watts and Stenner, 2012).

After the factor analysis is undertaken, the next stage in a Q study is to "rotate" the factors to make the individual Q sorts more closely associate with the factors. This process alters the position of the Q sorts relative to the factors without altering the relationship between the factors (Watts and Stenner, 2012). Varimax rotation is used to give the most objective solution, while hand rotation is normally used for hypothesis testing.

Automatic flagging is then used to select significant sorts for further analysis. A significant loading is one sufficiently high to assume there is a relationship between the sort and the factor in question. Sorts are typically selected if they are significant at the 99% confidence level and are "pure"; that is they do not load significantly on other factors. Those sorts which load on multiple factors are termed "confounded" and are not selected to explain a factor. The "flagging" of the Q sorts is necessary to select the participants whose Q sorts will be used to create the compounds sorts or factor arrays. The factor arrays are created through the use of weighted averages, with the Q sorts which load most on each factor having the most weight or influence in its composition. Once the factor array for each factor is generated, it is necessary to interpret it. Clearly the statements which have been ranked at the extremes of the scale need to be analysed as these are the ideas which loading participants feel most strongly about. However it is not sufficient to only consider the statements ranked +3, +4, -3 and -4 (Watts and Stenner, 2012). The data needs to be interpreted as a whole, as items placed in the middle of the distribution do not necessarily reflect ambivalence, rather that the participant feels more strongly about other items. Those items which are

ranked higher or lower than in any other factor can also be considered “salient statements (Watts and Stenner, 2012).

The data present in each factor array and the salient statements is then converted back into words to form a factor interpretation in order to summarise the shared subjectivity which a factor represents. To minimise researcher bias, during this stage the audio recordings made at the time of the Q sorts are often used. This ensures that each factor interpretation is based on participants responses as opposed to the researcher’s ideas of what a statement’s ranking might mean. In the interpretations, relevant statements (and their rankings) are linked together to form a plausible position and direct quotes from the recordings taken at the time of the Q sorts are used to further explain the participants’ subjectivity. Finally, the resulting factors are scrutinised to confirm they make sense (Webler et al., 2009).

Chapter 2 reviewed the relevant literature on risk perception and hurricane evacuation and argued that there is a perceptible bias towards the exogenous paradigms which treat risk as objective and defined outside of the person. Consequently there is a need to rebalance the literature in favour of endogenous paradigms which explain risk as internal to the person. The psychological and cultural paradigms of hurricane risk demonstrate not only that people think in different ways, but these ways are unpredictable and not always rational according to neo-classical economics. This suggests that conventional tools for answering questions of non-evacuation may not be useful. These decisions probably take place on several levels of consciousness and as such the respondent might not be able to fully explain his decision through a survey. A method such as Q, which goes deeper than superficial questions, could facilitate a deeper understanding. A Q study can give a more nuanced analysis of the factors contributing to subjective constructs as it facilitates the investigation of subjectivity as defined by stakeholders themselves. As a result in this thesis a Q study is used to unveil shared subjective evacuation attitudes which were important on Galveston at the time of Hurricane Ike.

4.5 Agent based modelling

The second research question is divided into two:

> 2.a. How do different subjective evacuation attitudes combine with subjective norms to create large scale patterns in hurricane evacuation?
>
> 2.b. How might changes in subjective evacuation attitudes, subjective norms and social networks alter large scale patterns in hurricane evacuation decisions?

This thesis takes the line that qualitative methods are the most appropriate for unveiling subjective understandings of risk. However, when it comes to assessing and synthesising the impact of subjective norms and social networks it can be argued that qualitative methods are less well suited. While it is possible to ascertain a person's subjective evacuation attitude from an interview, it is more difficult to ascertain if, how and when they were influenced by others through this method. Indeed a quantitative survey would also be problematic for the same reason; people do not know for certain the extent to which their decisions are influenced by others (Christensen and Ruch, 1980). Different quantitative methods therefore need to be considered to answer the second research question. One method which can be used to investigate this problem is computer simulation or modelling.

Modelling has acquired acceptance in climate change and disaster mitigation policy circles due to a demand for systemic and quantitative approaches. This has been shown through simulations of the effects of changing climates (Morrison and Addison, 2008), projected sea level rises (Sallenger Jr et al., 2012) and storm surge impacts (Westerink et al., 2008). Simulations and Geographical Information Systems can be useful in the aftermath of a disaster, and it is standard procedure to bring in local and international mapping experts to better understand impacts and to coordinate rescue attempts. Lindell and Prater (2007) have designed an evacuation management design support system, which helps the formation of hurricane evacuation policy by factoring

in minimum and maximum evacuation times compared with earliest and latest time of landfall.

Hurricane evacuations are a physical and social phenomenon with both physical and social drivers. There are large scale outcomes resulting from small scale interactions on both physical and social levels. On the social side, agents range from individuals and households through to media outlets, and local, state and federal governments and agencies. The interactions of these agents can have cumulative effects which are greater than the sum of their parts. When considering strategies to manage and facilitate hurricane evacuations it is therefore logical to consider these interactions. A set of tools which can be used to analyse these interactions are agent based models (ABMs). It is argued that ABMs represent a third way of doing science using simulation as opposed to deduction or induction (Axelrod, 2007). Simulation is distinct from traditional techniques as it involves the generation of data and creation of artificial societies which can then be analysed inductively. ABMs represent the constituent parts of a system with behaviour designed to imitate the real life component. They were conceived of in order to simulate agent interaction, and for this trait, they are well suited to modelling subjective norms and social networks, a key component of the TRA. ABMs have simulated social interaction to investigate diverse subjects including bio attacks (Carley et al., 2006), the spread of epidemics (Bagni, 2002), the fall of the Anasazi civilisation (Kohler et al., 2005) and how insurgencies develop (Bohorquez et al., 2009).

Agents populating ABMs normally have three important properties; reactivity, proactivity and sociability which work together to make the method robust and versatile (Kniveton et al., 2011). Reactivity refers to the ability to respond to events, and proactivity is the ability to behave according to objectives, which are determined by the modeller. Sociability is the ability to interact with other agents, reflected by agents communicating ideas and actions spreading. This means ABMs provide a way of simulating the interaction of individuals which exist in a population or another complex social system (Widener et al., 2013). Other forms of modelling cannot account for the fact that people act in a variety ways. For practicality, most other modelling

approaches such as discrete event simulation and system dynamics are based on assumptions from economic theory. In such models, individuals are usually depicted as economically rational and homogenous (Macal and North, 2010). In contrast, by using ABMs it becomes possible to undertake computations which do not adhere to these assumptions from economics. In an ABM, the rationality of an agent is not necessarily determined by narrow utility seeking goals and agents can be depicted as heterogeneous, with several groups represented with different properties. As a result, ABMs are able to represent individual agency more than other simulation methods; they can be concerned with the agents' subjective perspective, and therefore complement Q method.

ABMs were first developed from complexity theory using concepts derived from computer science and social science. In the same way that complexity theory suggests that complexities in natural science mean a hurricane in the Atlantic could be caused by a butterfly flapping its wings in Africa, in the social sciences a seemingly trivial event can lead to large scale unexpected events. As Zebrowski describes it: 'add a glitch, a metaphorical butterfly, to a complex process and sometimes you get an outcome no rational person would ever have expected' (Zebrowski, 1999, p. 266). The idea driving the creation of an ABM is to search for this metaphorical butterfly and understand its effect. ABMs can enable system level behaviour to arise, meaning patterns not written into the model can arise organically. This means that ABMs enable the investigation of emergence. One of the most iconic ABMs is Segregation (Schelling, 1971), which revealed the emergent behaviour in segregated housing patterns. This model demonstrated how seemingly trivial individual choices, in this case a marginal preference to live next to neighbours of the same race, can result in massive social consequences, such as segregated clusters of different races.

Agent based models like other computational tools have been critiqued for being too simplistic. This is because in order to make a society simulable, they have to reduce the complexity of human and social behaviour. This means there is a disconnect between the findings of the model and reality of a complex society. This is a fair criticism, but ignores the benefits of simplicity. Models do not have to be descriptive; useful

contributions to academia and policy can also be made with indicative models as they can reflect real-life results even if some of the assumptions are simplistic (Goldenfeld and Kadanoff, 1999). Although it is impossible to simulate all the intricacies of human decision making, the limits to possible evacuation decisions mean its modelling is feasible and useful. Therefore it is possible to design a simple decision making process to approximate this constrained behaviour considering external influences such as information, policies and interaction between the agents. ABMs have been designed to model bounded rational behaviour, their suitability has been explained as 'agent based models provide a robust and flexible framework for tuning the complexity of agents... behaviour, degree of rationality, ability to learn and evolve, and rules of interaction' (Castle and Crooks 2006, pp.14–15).

Another critique of ABMs is that the data produced by the model is a direct function of how the programmer sets up the model. Q method is a constructivist tool, so ABMs would appear to be contradictory as computation is often termed deterministic, positivist and reductionist. However, it can be argued that agent based modelling is not necessarily at odds with constructivism (Füllsack, 2013). This is because ABMs can produce emergent properties. Füllsack (2013) explains that if a subject matter exhibits properties which are a) not exhibited by its parts, and b) not explained by the laws which explain the parts, then the subject matter exhibits emergent properties. Emergence therefore cannot be explained by positivist theories of knowledge. A related critique is that researcher bias is potentially a problem, but one which can be minimised through using empirical data to parameterise the model. The model to be used in this study is enhanced through an explicit consideration of subjectivity via the Q study.

ABMs have been designed to simulate decisions in the context of climate change adaptation. A study on the Philippines found ABMs to be useful as they simulate dynamic changes in climate and market, but also in the dynamic adaptive process of individuals to the impacts of these change (Acosta-Michlik and Espaldon, 2008). Kniveton et al. (2011) have demonstrated the practicality of Grothmann and Patt's (2005) adaptation model by incorporating it into an ABM to model migration in

Burkino Faso. Hurricane evacuation ABMs have been designed, the majority of which pertain to evacuation logistics (Chen, 2008; Zhang et al., 2009; Huang et al., 2012;, Mesa-Arango et al., 2013). These models are mainly concerned with understanding how and when residents evacuate, in order to investigate traffic concerns and reduce the number of accidents which occur when large populations move quickly from threatened regions. ABMs have increasingly been used for educational purposes. Disaster Dynamics (Scharff and McGinnis, 2004) is a strategy game set on a Gulf Coast island, concerned with the interaction of hurricanes and decisions and is aimed at undergraduate students and government officials. Such models can be successful in making risks and opportunities tangible through an accessible medium for non-experts. They can also provide rigorous numerical data, often seen as necessary to free up funds for policy measures or for further research (Eden et al., 2005).

There have been few ABMs which address the impact of subjective norms and networks on hurricane evacuation. A recent publication demonstrates a typical approach using a mathematical model to investigate the influence of social networks (Hasan and Ukkusuri, 2011), using the threshold model of social contagion (Watts, 2002). One group of researchers have developed an ABM which simulates the decision to evacuate from a hurricane and the impact of social networks (Widener et al., 2013). There are two issues which arise from this model. Firstly the data on which the model is parameterised is based on demographic information. It does not attempt to simulate a past response to an evacuation; rather it combines demographic data for the geographical area being studied and borrows approximate evacuation rates from other studies. The base evacuation rate is a function of risk area, car ownership probability and hurricane experience. Therefore it can be seen that the numbers are generated thorough technical and socio-economic paradigms of risk perception. As the model is for a hypothetical hurricane, it doesn't consider 'temporal, spatial, behavioural, and transport-related factors' (Widener et al., 2013, p. 202). The exclusion of temporal factors means that relevant events such as the time of day, evacuation warnings and weather updates are not included in the model. The absence of behavioural factors means little subjectivity is afforded to the household, as their evacuation is determined by their characteristics as identified through demographic information.

The second issue with the study is the way in which the social networks are modelled; it uses a threshold model, whereby agents evacuate only when a certain percentage of their social network has evacuated. This particular method of modelling network influence is somewhat deterministic, as if a certain condition arises agents are programmed to automatically evacuate. This means agents are recognised as having limited agency, supporting the criticisms of ABMs creating rules that generate behaviour. The ABM designed as part of this thesis will build on and develop the niche developed by Widener et al. (2013). Firstly, the model in this thesis is based on a historical event, Hurricane Ike which impacted the case study area of Galveston Island. This means that unlike the Widener et al. model, empirical data for the hurricane can be used when parameterising the model. A Q study is used to unveil the subjective attitudes which individuals hold with regards to hurricane evacuation. Therefore the agents are differentiated and thus given individual subjectivity increasing the accuracy of the model. The data from the Q study is combined with raw unpublished survey data (Van Zandt, 2010) on evacuation rates to provide more detail and rigour. Secondly the influence on other agents is modelled through a simple probability function. This means that the more contacts within a network who have left, the more likely the agent is to leave, but there is no absolute number after which evacuation is inevitable; agents like the humans they represent are thus unpredictable and possess more subjectivity than the Widener (2013) model.

Designing an ABM tends to be a balance between two approaches (Macal and North, 2010). The KISS approach (Keep It Simple Stupid) promotes simulating the basics of the system, while the KIDS approach (Keep It Descriptive Stupid) attempts to model a system as realistically as possible. The goal of the KISS approach is usually to understand a process better or give indicative results, while the KIDS model uses as much data as possible to produce a detailed model which can be used to inform policy or to make accurate predictions. Regardless of the level of detail in the simulation, the fundamentals of designing an ABM are the same. Firstly a physical environment is created to approximate the real setting of the modelled phenomena. Secondly agents are designed with appropriate characteristics. Thirdly events can be created to

simulate actual relevant incidents which might impact behaviour. Lastly networks are designed to explain the basic patterns of interaction between the agents.

One of the main attractions of ABMs to the investigator is the ability to conduct post-ethnographic experiments and perform sensitivity tests by adjusting the initial settings and parameters to find the effect on results. This means that ABMs are able to overcome the limitation of the single case study as they enable the development of further examples to test and generate conclusions (Agar, 2004). These examples can confirm: 1) the original result was a plausible outcome; 2) that a range of different outcomes can result from the same explanations; and 3) in an altered environment, a different array of outcomes could result. This is useful for research and policy because it can show the driving forces of an event such as hurricane evacuation and how a small change (for example in the structure of social networks) could produce a different macro evacuation result.

The literature review argued that even though it is widely accepted that decisions are not made in isolation from society, there is a lack of research into the impact of subjective norms and the social networks which they operate through, on the decision to evacuate. It is likely that with recent advances in technology and social media social networks are becoming increasingly important, therefore it is important to improve the understanding of their impact. An ABM can generate simulations which other models cannot as agents can be programmed to exhibit certain behaviour and it can produce emergent behaviour. In this thesis the ABM will simulate how subjective evacuation attitudes revealed by the Q study can interact with subjective norms to produce society-level evacuation. In this way research question 2.a. can be addressed. The inputs to the ABM can then be altered in order to model what could happen if there were changes in attitudes, norms or networks and address research question 2.b.

4.6 Conclusion

This chapter has explained the methodology of the thesis, developed through the framework of the TRA. It has argued that a case study is the most suitable approach for

producing rich, context specific data and that mixed methods are necessary to give an original insight into the problem of hurricane evacuation. The Q study can give a rich understanding of the decision to leave or stay by revealing subjective evacuation attitudes. The ABM will be parameterised with empirically grounded rules of behaviour derived from the Q study and will introduce a subjective norm operating through a social network to test their impact on the evacuation decision. Although it has been argued that the two methods are rather different from an epistemological point of view, they do share a focus on subjectivity. Such integration has great promise for the understanding of society level risk behaviour and methodological development.

Chapter 5: Understanding Individual Subjectivity

5.1. Introduction

This is the first empirical chapter. It describes work undertaken using a Q study to investigate subjective evacuation attitudes. As the case study chapter stated, the evacuation policy of the City of Galveston is based on informing the public of the risk and providing underserved members of the community with transport off the island. However, a significant minority of residents typically fail to move out of affected areas which can result in death and injury, as well as dangerous and expensive rescues. The evacuation result for Galveston during Hurricane Ike was disappointing for policy makers with only 70-80% of the island's residents evacuating. It is clear that a "one size fits all" evacuation policy does little to address the complex factors which interact to produce subjective evacuation attitudes favouring a decision to leave or stay. A deeper understanding of the attitudes which influence evacuation decisions would be useful as this area is comparatively understudied in the academic literature and neglected in policy circles. The specific research question addressed in this chapter is the following:

1. How do subjective evacuation attitudes affect hurricane evacuation decisions?

This means that a method needed to be selected which could reveal Galveston residents' subjective evacuation attitudes, understood as comprised of underlying beliefs about evacuation, threat appraisal and coping appraisal. This chapter documents a Q study of 40 residents of Galveston, Texas used to reveal the shared subjective evacuation attitudes which influenced a people's decision to evacuate or not in the face of the oncoming Hurricane Ike in September 2008. Four different subjective evacuation attitudes are revealed; the Citizen who obeys the mandatory evacuation order, the Individualist who is not influenced by orders and stays and

weathers the storm, the Pragmatist who evacuates when he deems it too risky to stay and the Believer who thinks he is protected by God or needs to help others and stays. This study demonstrates that people have differentiated subjective hurricane evacuation attitudes, which lead to differentiated evacuation results.

5.2 The creation of the Q set

The fieldwork was undertaken in August and September 2010 on the island of Galveston, two years after Hurricane Ike made landfall. The first step was to decide which opinions would be used for the Q study and this was done by creating the concourse of all possible opinions. This meant research was conducted on opinions in Galveston concerning evacuation from Ike before the hurricane made landfall. In order to include a comprehensive range of outlooks, a wide variety of sources were used. Statements were garnered from local and national newspapers, local and network television, national radio stations, academic papers, official government reports, the blogosphere and social networking sites. The statements which came from these sources were made by emergency responders, city managers, journalists, academics but above all from residents of Galveston. A thorough search was conducted and was terminated only when new opinions and discourses reached saturation point (Glaser and Strauss, 1967). All opinions used to create the concourse were initially taken verbatim in order to preserve the natural language and minimise researcher bias (Webler et al., 2009).

It was decided that the Q set should be comprised of 36 statements as studies have shown that is a number which can produce valuable data (Barry and Proops, 1999). Perhaps more importantly 36 was a number which was considered manageable and would not be daunting or a chore for the participants to sort. The Q set must be representative of all of the opinions on the issue at hand which exist in the relevant community (Brown, 1980), to this end the statements in the concourse were divided into 9 broad thematic areas reflecting different subjectivities on hurricane risk and evacuation (table 5.1). The majority of these themes (A-G) are evident in the literature on the technical, socio-economic, psychological and cultural paradigms of risk

perception discussed in the literature review. They also reflect “threat appraisal” and “coping appraisal” in the framework of the thesis. Themes H and I are very broad and do not directly equate to hurricane evacuation literature, but were found to be important in the discourse surrounding Hurricane Ike in Galveston. They also reflect “beliefs about evacuation” in the framework of the thesis. The Q set was created by selecting four statements from each theme to represent different aspects of each theme. Each item was selected to make a unique contribution to the Q set, without repeating or ignoring an issue. If this is achieved then the participant is able to express their subjectivity without their voice being restricted (Watts and Stenner, 2012).

Table 5.1: The sampling of the statements or Q set

Theme	Statement number			
A. Subjectivity concerning officials and their actions	9	14	19	24
B. Subjectivity concerning the media	7	15	28	35
C. Subjectivity concerning property	4	8	13	27
D. Subjectivity concerning danger	3	5	10	20
E. Subjectivity concerning past experiences	21	32	33	34
F. Subjectivity concerning agency	16	18	23	29
G. Subjectivity concerning ability to evacuate	2	17	25	26
H. Subjectivity concerning the community	11	12	31	36
I. Underlying attitudes	1	6	22	30

Some of the statements were re-worded to ensure a balance between positively and negatively worded statements (Webler et al., 2009). A pilot study was conducted on four participants drawn from a study on hurricane Ike (Van Zandt, 2010). Through this phase, the Q set was fine tuned. Two statements were edited from the Q set as they were deemed of little relevance, two others were altered to make the language less confusing or easier to understand and two new statements were added which the participants thought covered important issues which had been overlooked. The cards were reprinted and assigned a number at random in order to help analysis. The statements were translated into Spanish with the help of a student from Texas A&M University who is a member of the Galveston Hispanic community.

5.3 The selection of the P set

It was decided to interview 40 residents as it has been shown increasing the number over this figure is unlikely to yield significantly different results (Brown, 1980). As the research is centred on finding out how people make evacuation decisions, participants were drawn from those resident and present in Galveston at the time of Hurricane Ike; in other words the people who had to make the decision to evacuate or weather the storm. As the goal of the Q study was to reveal the shared subjective attitudes to hurricane evacuation, it was important to include a wide and balanced range of participants. Interviewees broadly representative of Galveston in terms of ethnicities, gender, age, education, income and housing were sought (table 5.2). Data from the 2000 Census was used to help structure the selection of participants (US Census Bureau, 2000).

Initially several participants involved in the Van Zandt (2010) study were interviewed and then a combination of snowball and convenience sampling was used. In addition to these techniques, targeted sampling was employed by contacting four local charities and two local branches of ethnic interest groups to facilitate interviews. In this way residents who do not speak English as a first language, marginalised and at-risk residents were recruited, bolstering the claim to a comprehensive range of participants. Q sorts and interviews were also undertaken with participants who could be termed “experts”; the City Manager, the Mayor at the time of the study, the City Public Information Officer and a local weather journalist. The vast majority of the participants could be described as a head of the household. Two younger participants who lived with their parents described themselves as the main decision makers at the time of the hurricane as they were either the only English speaker or the most educated person in the household.

Table 5.2: The sampling of the participants or P set

Evacuated		Ethnicity		Gender		Age		Education		Income in $		Housing	
Yes	26	Caucasian	16	M	22	21-30	6	Some school	1	0-20,000	7	Detached house	26
No	14	African American	10	F	18	31-40	5	High school graduate	7	20,000-40,000	11	Attached house	5
		Hispanic	11			41-50	4	Some college	12	40,000-60,000	6	Apartment	6
		American Indian	1			51-60	13	College graduate	11	60,000-80,000	4	Mobile home	1
		Italian	1			61-70	11	Post graduate	9	80,000-100,000	2	Squat	1
		Asian	1			71-80	1			>100,000	9	Hostel	1
										No answer	1		

5.4 The Q sorting process

The participants were asked to sort the 36 statements printed on laminated cards into three piles; agree, disagree and indifferent. The participants were then asked to further sort these three piles onto a normal distribution shaped grid. The columns of the grid were labelled from +4 (strongly agree), through zero to -4 (strongly disagree) as in figure 4.2. The instruction was given that the participant should perform the sort according to how they were feeling in the days leading up to the landfall of Hurricane Ike. It was important to stipulate that the study only concerned this time, and was not concerned with what occurred later. The participants were also asked to “think aloud” whilst undertaking the sorting process, in order that their thoughts and words could be documented and recorded by the researcher. After the sort was completed the participants were asked to explain some of their choices to produce context for analysis. Once the participant was satisfied with the sort, the results were recorded by writing the position of each statement on a blank sheet of paper. Finally some questions were asked about if and when the participants evacuated, and to attain demographic characteristics.

5.5 Factor analysis

In the next stage, factor analysis was used as a method of data reduction to distil the main shared subjective understandings. The programme PQ Method[2] was used for the analysis. Principal components analysis was used as the 'mathematically *best* solution' for factor analysis (Watts and Stenner, 2012, p. 99). For this study a four factor solution was selected as the most suitable as each factor had an Eigenvalue of over two, satisfied Humphrey's rule and had several loading sorts but also, crucially each factor presented a distinct and plausible subjective attitude on hurricane evacuation. Initially varimax rotation was used to give the most objective solution as it maximises variance. Thereafter minimal hand rotation was used to increase the number of participants loading on one and only one factor. Subsequently, the correlation between the remaining factors was examined to ensure distinctiveness.

Automatic flagging was used to select pure significant sorts at the 99% confidence level. Sorts which scored 0.43 or more for a factor were selected, but only if they did not load heavily on another factor. The four factors which emerged were defined by 19, 8, 4 and 5 sorts explaining 26%, 12%, 9% and 9% of the variance respectively for a total of 56% of the variance explained (table 5.3). Over 35% of the variance explained is normally considered adequate (Kline, 1994), therefore over 50% can be considered a very satisfactory solution. Through flagging, the 40 perspectives were reduced to 4 ideal sorts (table 5.4).

[2] PQMETHOD is a DOS based freeware programme by Peter Schmolck. Contact: Peter.Schmolck@unibwmuenchen.de.

Table 5.3: The factor matrix ("X" indicating pure loadings[3] confounded sorts in grey)

Sort number	Evacuated?	Factor 1	Factor 2	Factor 3	Factor 4
1	No	-0.182	0.657 X	-0.125	0.421
2	No	0.0654	0.727 X	-0.0061	0.253
3	Yes	0.517 X	0.186	0.0405	0.389
4	Yes	0.0755	0.206	0.588 X	0.0503
5	Yes	0.39	0.114	0.384	0.218
6	No	0.0091	0.0311	0.126	0.707 X
7	Yes	0.366	0.385	0.446 X	0.313
8	Yes	0.313	0.647 X	0.0252	0.0402
9	No	0.705 X	-0.0583	0.104	0.0904
10	Yes	0.354	0.462 X	0.264	0.384
11	No	0.101	0.641 X	0.421	0.187
12	Yes	0.816 X	0.232	0.0098	0.219
13	Yes	0.451	0.0064	0.658 X	0.0322
14	No	0.061	0.325	0.0344	0.592 X
15	Yes	0.762 X	-0.120	0.34	0.132
16	Yes	0.284	0.0927	-0.349	0.576 X
17	Yes	0.791 X	0.267	0.0986	-0.0523
18	Yes	0.373	0.316	0.0577	0.438 X
19	Yes	0.552 X	0.38	0.158	-0.127
20	Yes	0.607 X	0.13	-0.0098	0.361
21	No	0.553	0.437	0.459	-0.108
22	Yes	0.734 X	-0.148	0.181	0.275
23	No	0.163	0.242	0.11	0.54 X
24	Yes	0.357	0.496 X	-0.101	-0.269
25	No	-0.207	0.709 X	0.354	0.246
26	Yes	0.794 X	0.196	0.1	-0.031
27	Yes	0.738 X	0.335	0.171	0.032
28	Yes	0.557 X	0.0035	-0.159	0.336
29	Yes	0.723 X	0.163	0.002	0.144
30	No	0.521 X	0.284	-0.108	0.0588
31	Yes	0.812 X	0.112	0.153	-0.0053
32	No	0.163	0.0566	-0.691	0.141
33	Yes	0.636 X	-0.197	0.003	0.214
34	Yes	0.401	0.447	0.101	0.402
35	No	0.141	0.616 X	0.265	0.0838
36	Yes	0.071	0.0733	0.708 X	0.467
37	Yes	0.499 X	0.065	0.358	-0.0262
38	Yes	0.717 X	0.0336	0.221	0.289
39	Yes	0.72 X	0.17	-0.262	0.0342
40	Yes	0.609 X	0.232	0.0697	0.46
Pure loadings	36	19	8	4	5
Evacuated	28	17	3	4	2
Variance		26%	12%	9%	9%

[3] The statements were selected at the 99% confidence level using the following formula:
= ± 2.58 x 1/√40 (the number of statements in the Q set) = ± 0.43

Table 5.4: Idealised factor scores by statement

	Statement	Ideal score			
1	You just have to put up with this stuff some of the time to live in paradise most of the time.	1	4	1	0
2	Family is the main consideration.	4	4	0	4
3	I don't know how long it will be before the roads close.	1	0	1	0
4	It's only a category 2. My home is very structurally sound. I'll be OK.	-2	2	1	2
5	I'm not going now as the traffic is so bad.	-3	0	1	1
6	I don't want anybody to have to risk their life to come get me. When you stay behind you put the first responders at risk as well.	2	1	4	-1
7	The hype and exaggeration from TV weather people is off putting and designed to increase ratings.	-1	2	-1	-2
8	I need to prepare my house before the hurricane.	4	3	4	3
9	The government treatment of hurricanes is inconsistent from one to the next.	0	2	-1	-1
10	Evacuation is inconvenient. But it is not worth risking your life to stay.	3	-1	3	1
11	I'm not gonna make my decision based on what other people are doing. I'm sticking to my plan.	2	1	3	1
12	I know who to call at the city if I need help.	0	0	3	1
13	This is home. I'm going to stay here come hell or high water.	-4	-2	-1	2
14	The evacuation was called late.	0	0	0	-2
15	Persons not evacuating in single-family or two storey homes will face certain death.	-1	-4	-4	0
16	I'm tired of running from these damn things. If it's gonna get you it's gonna get you.	-4	-3	-1	2
17	If I don't tough it out I'm afraid of losing my job.	-3	-1	-3	-3
18	I can't leave. I am trapped by the idea of vandalism and theft.	-2	-2	-2	-1
19	Still absolutely positively no reason to say police can use force to make someone evacuate. It's absolutely a loss of liberty.	-1	3	0	0
20	I don't expect to have too much water. I'm more worried about wind.	0	1	-3	-4
21	I was in the middle of the evacuation of Rita and I don't want to go through that again.	1	0	-1	2
22	Now it's time to start drinking and have a hurricane party.	-4	-3	0	-4
23	I just have to believe God will make a way for us.	1	1	-4	3
24	Every hurricane is not the same. When people are told to evacuate they should evacuate.	3	-1	2	-1
25	Gas and stuff is high. But you can't look at all that. I think my life is more valuable than high gas prices.	4	2	4	4
26	I can't leave without my pets.	0	3	2	-1
27	If there is flood water I'll lose my car.	0	-1	2	0
28	The hurricane people aren't doing a good job. The storm's trajectory keeps changing.	-2	0	-4	-4
29	It's not stupidity or insanity or even pride that keeps most people in their homes during a storm: It's hope.	-1	1	0	3
30	Why do we need to help people evacuate? The government shouldn't be expected to do everything.	-2	-4	1	-3
31	I can't stay in Galveston if the whole city leaves.	2	-2	-2	-2
32	There's no excuse for staying behind after Katrina and seeing what happened there.	3	-4	0	1
33	I am going to evacuate because I always evacuate.	1	-3	-2	-3
34	Re-entry is a hassle. I need to be here to clear up.	-1	4	2	4
35	I don't have very much trust and confidence in the weather and anybody else telling me to leave or stay or anything like that.	-3	-1	-2	-2
36	I am worried about being in Galveston without services after the hurricane hits.	2	-2	-3	0

In order to make the factor arrays, statements ranked +3, +4, -3 and -4 were considered in addition to those items which were ranked higher or lower than in any other factor (Watts and Stenner, 2012). In the interpretations, relevant statements (and their rankings) are linked together to form a plausible position regarding

hurricane evacuation, and direct quotes from the recordings taken at the time of the Q sorts are used to further explain the participants' subjectivity. Demographic information is given at the beginning of each interpretation to enable further analysis.

5.6 Factor 1: The Citizens

Table 5.5: Factor 1 - The Citizens

Evacuated		Ethnicity		Gender		Age		Education		Income in $		Housing	
Yes	17	Caucasian	4	M	8	21-30	5	Some high school	0	0-20,000	3	Detached house	13
No	2	African American	6	F	11	31-40	1	High school graduate	4	20,000-40,000	7	Attached house	1
		Hispanic	8			41-50	2	Some college	7	40,000-60,000	3	Apartment	4
		American Indian	0			51-60	6	College graduate	5	60,000-80,000	1	Mobile home	0
		Italian	0			61-70	5	Post graduate	3	80,000-100,000	0	Squat	1
		Asian	1			71-80	0			>100,000	4	Hostel	0
										No answer	1		

Factor 1 explains 26% of the study variance. It was decided to term participants loading on the first factor "Citizens" as they conform to the kind of attitudes that policy makers expect and want. This is manifested through the carrying out of the mandatory evacuation order. Citizens have respect for the authorities and their rules as well as experts and their advice. They seem to believe the threat is real, trust the government's appraisal of the risk and evacuate due to this trust and their own risk adverse nature. There were nineteen participants loading as Citizens (table 5.5). Seventeen of them evacuated including the Mayor and the City Manager. The Citizens are a multi-ethnic group, with only four Caucasians. The two Citizens who did not evacuate claimed they would have done had they had the option; participant 9 was not able to leave due to his position in local government, while participant 30 wanted to leave but missed his ride due to a misunderstanding.

Table 5.6: Salient statements for the Citizens

	Statement	Ranking
2	Family is the main consideration.	+4
4	It's only a category 2. My home is very structurally sound. I'll be OK.	-2
5	I can't leave now the traffic is so bad.	-3
8	I need to prepare my house before the hurricane.	+4
10	Evacuation is inconvenient. But it is not worth risking your life to stay.	+3
13	This is home. I'm going to stay here come hell or high water.	-4
16	I'm tired of running from these damn things. If it's going to get you, it's going to get you.	-4
17	If I don't tough it out I'm afraid of losing my job.	-3
19	Still absolutely positively no reason to say police can use force to make someone evacuate. It's absolutely a loss of liberty.	-1
22	Now it's time to start drinking and have a hurricane party.	-4
24	Every hurricane is not the same. When people are told to leave they should leave.	+3
25	Gas and stuff is high. But you can't look at all that. I think my life is more important than high gas prices.	+4
29	It's not stupidity or insanity or even pride that keeps most people in their homes during a storm: It's hope.	-1
31	I can't stay in Galveston if the whole city leaves.	+2
32	There's no excuse for staying behind after Katrina and seeing what happened there.	+3
33	I am going to evacuate because I always evacuate.	+1
34	Re-entry is a hassle. I need to be here to clear up.	-1
35	I don't have very much trust and confidence in the weather and anybody else telling me to leave or stay or anything like that.	-3
36	I am worried about being in Galveston without services after the hurricane hits.	+2

Citizens were more likely than the other groups to evacuate habitually (33), less inclined to think that re-entry after evacuation is problematic (34) and less likely than other groups to understand non-evacuation (29). For Citizens the inconvenience or cost of evacuation is outweighed by the risk of staying (10 and 25). During the interviews many of the citizens demonstrated a healthy respect for nature one participant claiming 'safety comes before anything' and 'it's not worth risking your life'. The importance of family (2) was stressed, 'kids are the most important thing; everything else goes out the window'. This idea continued with one interviewee expressing his opinion that (13) 'there is no such place as home' although in general Citizens expressed a need to prepare their homes before the hurricane arrived (8). Citizens were less likely to think that their homes were safe enough to weather a storm

(4). The idea of a hurricane party was dismissed (22) because 'that's absolutely stupid in the face of impending danger'. The importance of Katrina (32) was highlighted by one participant who explained 'Katrina's victims mirrored Galveston – the African American community'. Most of the Citizens left after the evacuation order was issued, meaning routes closing would not have been an issue (5), one participant stating 'they give you enough time'. Citizens were more likely to feel less able to cope independently in Galveston had they remained as being alone (31) or without services (36) would be undesirable or inconvenient.

Those loading as Citizens typically also displayed a respect for authority or the judgement of those in authority (24 and 35), one participant explaining 'I trust the weather people' and another 'I defer to experts'. Other participants were more explicit about why they left; 'I evacuated because they told us'. Another participant revealed 'I usually evacuate because the mayor says it's time to go'. Others saw the order as 'not subjective' and something which must be accepted and carried out, one stating 'I'm not gonna go against social order' and another that 'everybody's got to follow the rules'. This was explained as 'the Government is getting smarter; it's refining decisions'. Although the evacuation order was highlighted as important by the Citizens, it did not have the same significance for everyone. For instance, one participant explained the role of the evacuation order in the decision making process thus; 'as you're making this decision, weighing up factors, the city evacuation order makes things align'. This suggests for some residents the evacuation order worked with other sources of information to influence the final decision. The Citizens were also more inclined than other groups to support the use of force to ensure evacuation (19).

5.7 Factor 2: The Individualists

Table 5.7: Factor 2 - The Individualists

Evacuated		Ethnicity		Gender		Age		Education		Income in $		Housing	
Yes	3	Caucasian	6	M	6	21-30	0	Some high school	0	0-20,000	1	Detached house	6
No	5	African American	1	F	2	31-40	1	High school graduate	0	20,000-40,000	1	Attached house	1
		Hispanic	0			41-50	1	Some college	2	40,000-60,000	1	Apartment	1
		American Indian	0			51-60	3	College graduate	2	60,000-80,000	0	Mobile home	0
		Italian	1			61-70	2	Post graduate	4	80,000-100,000	2	Squat	0
		Asian	0			71-80	1			>100,000	3	Hostel	0
										No answer	0		

The second factor accounts for 12% of the study variance. Participants loading on the second factor were named “Individualists” as they appeared to be independent thinkers unlikely to be influenced by third parties. They are sceptical of the media, which they view as motivated not by informing the public, but by creating hype to attract viewers or sell newspapers. They are critical of the government, which is seen as not having a clear policy on evacuation. They tend to conceptualise hurricanes as more of an inconvenience than a threat to their lives or property. There were eight participants loading as Individualists and five of them weathered the storm (table 5.7). Six of the participants were male and two female. Six of the participants were Caucasian, including all five non evacuators. All of the eight Individuals had some higher education, with four attaining a post-graduate qualification. The Individualists had the highest average income of the four factors. Two of the participants who did evacuate were family men with young children. During their interviews they both stated they would not have left if they had been single. The remaining participant was persuaded to evacuate by his daughter who lives in another city.

Table 5.8: Salient statements for the Individualists

	Statement	Ranking
1	You just have to put up with this stuff some of the time to live in paradise most of the time.	+4
2	Family is the main consideration.	+4
7	The hype and exaggeration from TV weather people is off putting and designed to increase ratings.	+2
8	I need to prepare my house before the hurricane.	+3
9	The government treatment of hurricanes is inconsistent from one to the next.	+2
10	Evacuation is inconvenient. But it is not worth risking your life to stay.	-1
15	Persons not evacuating in single-family or two storey homes face certain death.	-4
16	I'm tired of running from these damn things. If it's going to get you, it's going to get you.	-3
17	If I don't tough it out I'm afraid of losing my job.	-1
19	Still absolutely positively no reason to say police can use force to make someone evacuate. It's absolutely a loss of liberty.	+3
20	I don't expect to have too much water. I'm more worried about wind.	+1
22	Now it's time to start drinking and have a hurricane party.	-3
25	Gas and stuff is high. But you can't look at all that. I think my life is more valuable than high gas prices.	+2
26	I can't leave without my pets.	+3
27	If there is flood water I'll lose my car.	-1
28	The hurricane people aren't doing a good job. The storm's trajectory keeps changing.	0
30	Why do we need to help people evacuate? The government shouldn't be expected to do everything.	-4
32	There's no excuse for staying behind after Katrina and seeing what happened there.	-4
33	I am going to evacuate because I always evacuate.	-3
34	Re-entry is a hassle. I need to be here to clear up.	+4
35	I don't have very much trust and confidence in the weather and anybody else telling me to leave or stay or anything like that.	-1

One clear theme which emerges from the sorts and interviews with the Individualists is a comparatively low perception of risk. One participant expressed that Galveston 'has its bad points such as storms, but it's worth the risk' (1). The majority of Individualists felt they were not risking their lives, one stating 'we were in a safe place…we knew we weren't at risk' (10). They believed that their lives were more important than high gas prices, but this was less salient than for the other factors, as they believed their lives were not in danger (25). For Individualists, evacuation is certainly not a default position.

One participant proudly explained (33) ‘I stayed because my family’s never left’. Most of the participants expressed that they didn’t regret their decision ‘I’ll do it all over again’ and another that ‘if a category 5 were coming, I might leave’. Individualists thought that parallels with Hurricane Katrina were unhelpful; ‘this is not New Orleans, this is not a bowl’ (32). A motivation for staying was explained as ‘it’s difficult to get back - even with credentials’ (34). However the motivation to party did not influence Individualists (22), with one participant expressing ‘you gotta stay sober and have your mind on everyone’ another indicating ‘now that’s stupid…it’s not the time to party, it was work mode’. The necessity to stay due to work commitments did not influence the Individualists (17). There is however, also evidence that some of the participants were badly informed about the necessity to evacuate; ‘I was totally caught off guard…I didn’t think about the storm surge’ and I had ‘no idea it was going to be as bad as it was’. Relative to the other factors, the Individualists were more concerned about the dangers of wind as opposed to water (20); this might explain why they were also the least concerned about damage to their cars (27). One of those who did evacuate told how ‘my plan can be changed based on last minute changes’ and another that ‘I was conflicted’.

The individualists seemed to make independent decisions and there was a degree of scepticism over the role played by the authorities. The certain death statement (15) was seen as ‘a little bit overboard’ and another participant explained ‘I wasn’t worried about this…hype’. Policies concerning hurricane evacuation were viewed as confusing (9). The idea that police could enforce evacuation (19) was seen as ‘unenforceable and a ludicrous assumption’. However under this view the Government is seen as playing an important role helping those unable to evacuate independently (30); with one participant claiming ‘we have to help people who can’t help themselves’. Related to the lack of faith in the authorities, respondents loading as Individualists seem to possess a high level of individual agency. They did not believe in fate (16), instead stating ‘you make your own destiny’ and to think otherwise ‘is throwing caution to wind’. In addition to the lack of faith in government it was also possible to discern relative to the other factors, a lack of faith in the coverage of the hurricane by the media and the forecasts of experts (7, 28 and 35).

5.8 Factor 3: The Pragmatists

Table 5.9: Factor 3 - The Pragmatists

Evacuated		Ethnicity		Gender		Age		Education		Income in $		Housing	
Yes	4	Caucasian	4	M	3	21-30	0	Some high school	0	0-20,000	0	Detached house	3
No	0	African American	0	F	1	31-40	1	High school graduate	0	20,000-40,000	1	Attached house	0
		Hispanic	0			41-50	0	Some college	1	40,000-60,000	1	Apartment	0
		American Indian	0			51-60	1	College graduate	2	60,000-80,000	1	Mobile home	1
		Italian	0			61-70	2	Post graduate	1	80,000-100,000	0	Squat	0
		Asian	0			71-80	0			>100,000	1	Hostel	0
										No answer	0		

The third factor explains 9% of the variance. Participants loading on the third factor are named “Pragmatists” due to their practical, risk adverse attitudes. They appear to listen to the advice of the government, the weather experts and the media but will make a personal informed decision in their own time. This tended to result in the decision to evacuate coming later, perhaps when the risk of impact became more likely or certain. There were four participants loading as Pragmatists including the weather reporter, all of whom were Caucasian and evacuated (table 5.9). Three of the participants were male; all had at least some college education, with two college graduates and one post graduate. All of the Pragmatists reported having previous experience of hurricanes.

Table 5.10: Salient statements for the Pragmatists

	Statement	Ranking
2	Family is the main consideration.	0
6	I don't want anybody to have to risk their life to come get me. When you stay behind you put the first responders at risk as well.	+4
8	I need to prepare my house before the hurricane.	+4
10	Evacuation is inconvenient, but it's not worth risking your life to stay.	+3
11	I'm not gonna make my decision based on what other people are doing. I'm sticking to my plan.	+3
12	I know who to call at the city if I need help.	+3
15	Persons not evacuating in single-family or two storey homes face certain death.	-4
17	If I don't tough it out I'm afraid of losing my job.	-3
20	I don't expect to have too much water. I'm more worried about wind.	-3
21	I was in the middle of the evacuation of Rita and I don't want to go through that again.	-1
22	Now it's time to start drinking and have a hurricane party.	0
23	I just have to believe God will make a way for us.	-4
25	Gas and stuff is high. But you can't look at all that. I think my life is more important than high gas prices.	4
27	If there is flood water I'll lose my car.	+2
28	The hurricane people aren't doing a good job. The storm's trajectory keeps changing.	-4
30	Why do we need to help people evacuate? The government shouldn't be expected to do everything.	+1
36	I am worried about being in Galveston without services after the hurricane hits.	-3

The Pragmatists perceive the hurricane as a very real threat. They were well prepared and typically had their finances in order (25); 'I have an emergency budget for it'. They were informed about the threat level (10), explaining 'the tidal surge motivated me' and demonstrated a good understanding of the structure of hurricanes 'you look at the clean and dirty side' (20). There was also an understanding of the multiple risks that come with a hurricane. One participant highlighted that the wind and storm surge were not the only danger; 'there is not just one set of circumstances…fire, debris'. Utilising this information in addition to the warning of certain death (15) meant that 'there's no reason to be caught out'. Another perceived risk was to cars, and Pragmatists were the factor most concerned about the possibility of damage to their vehicles (27). Family was less of a motivation for evacuation compared to the other factors (2), and experiences evacuating from Hurricane Rita were not a major factor in

the decision to leave (21). There was also a desire not to put first responders at risk (6), as by staying 'you put staff in jeopardy'. Pragmatists, unlike the other factors thought that people should be able to evacuate independently of government (30).

Those loading as Pragmatists were confident that they could make a competent, independent decision about the necessity to evacuate. They felt in control of their actions (23) as 'we choose our own destiny' and 'God gave us a brain to make our own decisions'. This theme of agency was further developed; one participant stating 'I am confident with close call judgements' so the decision to evacuate 'depends on my sense of danger'. Another participant explained (11) 'I use my own judgement; trust it more than anyone else'. In general Pragmatists thought the experts do a good job in terms of predicting the landfall of the hurricane (28) stating 'there's no way of knowing' and that 'they're doing the best they can'. On the whole, the Pragmatists came across as well informed and well connected (12), one alluding to 'connections in the city' which could be of use in the event of an emergency. Although all of the Pragmatists evacuated, they gave the impression that living in Galveston without services would not have been too difficult as it is 'a given' and merely requires 'basic camping skills' (36).

5.9 Factor 4: The Believers

Table 5.11: Factor 4 - The Believers

Evacuated		Ethnicity		Gender		Age		Education		Income in $		Housing	
Yes	2	Caucasian	0	M	3	21-30	0	Some high school	0	0-20,000	2	Detached house	1
No	3	African American	3	F	2	31-40	1	High school graduate	2	20,000-40,000	1	Attached house	3
		Hispanic	2			41-50	0	Some college	2	40,000-60,000	0	Apartment	1
		American Indian	0			51-60	3	College graduate	1	60,000-80,000	2	Mobile home	0
		Italian	0			61-70	1	Post graduate	0	80,000-100,000	0	Squat	0
		Asian	0			71-80	0			>100,000	0	Hostel	0
										No answer	0		

The fourth factor also explains 9% of the study variance. Participants loading on this factor are termed "Believers" to signify their spiritual faith, but also their trust in the

government, weather people and media. For some of the Believers, their spiritual faith is a sufficient response to the threat posed, while for others this is manifested in a desire to stay and help others unable to help themselves. There were five participants loading as Believers (table 5.11). Three of the participants stayed and weathered the storm, all of whom were male. The two Believers who did evacuate were women and evacuated quite late. All of the Believers were either African American or Hispanic and four were born on the island, the other having lived there for 21 years.

Table 5.12: Salient statements for the Believers

	Statement	Ranking
2	Family is the main consideration.	+4
6	I don't want anybody to have to risk their life to come get me. When you stay behind you put the first responders at risk as well.	-1
7	The hype and exaggeration from TV weather people is off putting and designed to increase ratings.	-2
8	I need to prepare my house before the hurricane.	+3
13	This is home. I'm going to stay here come hell or high water.	+2
14	The evacuation was called late.	-2
15	Persons not evacuating in single-family or two storey homes will face certain death.	0
16	I'm tired of running from these damn things. If it's gonna get you it's gonna get you.	+2
17	If I don't tough it out I'm afraid of losing my job.	-3
20	I don't expect to have too much water. I'm more worried about wind.	-4
21	I was in the middle of the evacuation of Rita and I don't want to go through that again.	+2
22	Now it's time to start drinking and have a hurricane party.	-4
23	I just have to believe God will make a way for us.	+3
25	Gas and stuff is high. But you can't look at all that. I think my life is more valuable than high gas prices.	+4
26	I can't leave without my pets.	-1
28	The hurricane people aren't doing a good job. The storm's trajectory keeps changing.	-4
29	It's not stupidity or insanity or even pride that keeps most people in their homes during a storm: It's hope.	+3
30	Why do we need to help people evacuate? The government shouldn't be expected to do everything.	-3
33	I am going to evacuate because I always evacuate.	-3
34	Re-entry is a hassle. I need to be here to clear up.	+4

For those classified as Believers, evacuation was not the norm, with one interviewee explaining (33) 'I don't evacuate for storms'. There seemed to be an inclination to stay

at home, even if the Believers perceived a risk, perhaps due to a deep association with place (13). Evacuation was something to be avoided due to previous inconvenience (34), in particular negative experiences during Hurricane Rita 'I evacuated for Rita and nothing happened' (21). Family was very important to the Believers with one man explaining 'I had to stay for my family' (2). Some agreed the hurricane could be dangerous (20), one participant explaining 'you expect water, that's common sense' and another 'I knew how large the storm was; people told me to go'. However one participant claimed 'I didn't think it would be that bad'. The impact of authorities was divisive (28) with one participant claiming 'the Mayor did an excellent job', but another with the opinion that 'the weather people dropped the ball'. Unlike the other factors, they generally thought that the evacuation was called in time (14) and did not feel strongly about the certain death statement (15). In contrast to the other factors, Believers thought that first responders should risk their lives to rescue people (6). The Believers were unique in thinking that the media coverage of the hurricane was appropriate (7). The fact that most of the Believers stayed and weathered the storm was not related to a desire to party (22), as the hours before landfall were seen as a 'time to start making preparations'. The Believers were not especially concerned about their pets (26).

It could be argued that some of the Believers seem to be dependent decision makers, although this relative lack of agency did not come from employers forcing them to stay (17). As one participant put it 'I don't really give a shit about jobs'. In contrast to the other factors, the Believers seem to be fatalistic, believing that the hurricane or even death might be unavoidable; 'there were some people who left for the hurricane and they was on a bus and the bus had an accident and they died' (16). Another way of interpreting this fatalism is faith; some of the Believers had faith that a higher being would protect them (23) one explaining that 'God will look after you'. For one of the evacuating Believers, religious faith made her more likely to evacuate as 'God gives us the ability to make the right decision'. The idea of hope was related to faith; 'their hope or faith is such that they have faith in God' (29). Another participant went further by stating 'I made a decision to stay in the name of Jesus…I don't leave unless the spirit of God tells me'. He explained that this is because 'every time I stay there's always

been someone I've been able to help'. However, Believers do not think that God and faith are the only decisive factors in the decision to evacuate. They accept a role for the government in evacuation (30), as one participant put it 'not everyone is at the same level'.

5.10 Issues of consensus

Table 5.13: Statements of consensus

	Statement	1	2	3	4
3	I don't know how long it will be before the roads close.	1	0	1	0
8	I need to prepare my house before the hurricane.	4	3	4	3
11	I'm not gonna make my decision based on what other people are doing, I'm sticking to my plan.	2	1	3	1

The rankings of three statements were not distinguished across any of the pairs of factors. These items are therefore termed "consensus statements", representing themes about which the four factors had broadly similar opinions (table 5.13). Each factor was somewhat neutral about statement 3, compared to other statements. This could suggest that anxiety about when evacuation routes will close is not an issue participants considered in the days and hours leading up to the landfall of the hurricane. However the fact the respondents did not rank this statement as salient does not necessarily mean it was unimportant, rather that it was less important relative to other statements. Indeed one respondent explained its relevance for him; 'I left when I heard there might not be a way out'. All four discourses agreed strongly with statement 8. This is understandable as regardless of the attitude of the participant towards evacuation, they seem to accept the need to prepare their homes. What form this preparation will take is another question. One participant who evacuated explained 'I had to get the house ready before I left', whereas another participant who stayed said 'I can't imagine someone going into a storm not being prepared'.

Finally all factors agreed somewhat with statement 11, suggesting a belief that social networks are of limited importance compared to evacuation plans when making the final decision to leave or stay. It could be seen as surprising that Individualists did not rank this statement higher, but from recordings it is clear that while they agreed with the statement, they felt more strongly about other statements, hence ranked it relatively lowly. One participant explained her agreement with the statement by claiming 'I'm not gonna get talked out of something'.

5.11 Confounded sorts

It is normal that not all participants identify with one and only one factor. This can be because a participant's subjectivity is not represented by any of the factors, or that they are "confounded"; that is they load significantly on two or more factors. Participant 5 did not load significantly on any of the factors; he was split between factors 1 and 3. On closer examination, the reason for this could be that he evacuated later than his family. Therefore it might be that his own behaviour was Pragmatic, while his family acted as Citizens. Participant 21 loaded on factors 1, 2 and 3. From the interview recording it is apparent that the perspective of the participant might be explained through her personal circumstances. While she expressed a desire to leave for her own safety, this seems to have combined with a feeling of duty to stay due to her position as a City of Galveston employee. As a result she displayed the traits of being a Citizen, Individualist and Pragmatist. Finally participant 34 has a perspective comprised of factors 1, 2 and 4. An examination of the audio recording can again go some way to explain this result. This participant was initially reluctant to evacuate as she felt safe, but later changed her mind and evacuated. It seems that this participant changed her subjective evacuation attitude during in the days leading up to the landfall, so began thinking as an Individualist or Believer, and ended with the attitude of a Citizen.

Participant 32 loaded negatively on factor three, however after closer inspection of the sort and of the recording of the participant's own explanation of his sort, it seemed probable that he had been confused by the instructions given for conducting the

sorting process. Therefore his sort was not flagged as representing factor three as it is doubtful it represented his subjectivity (Webler et al. 2009).

5.12 Evacuation result of each subjective evacuation attitude

A fuller discussion of the results of from the Q study is in chapter 7, which links the results to the literature which was introduced in chapter 2. For now it is necessary to briefly discuss the findings of the Q study which are most relevant for the following chapter. This study has shown that people's subjective attitudes towards hurricanes and evacuation in the face of hurricanes vary, suggesting that homo economicus is indeed 'fantastical' (Gowdy, 2008). Each factor does not represent only one evacuation result (table 5.14), therefore evacuation result is not a function of subjective hurricane attitudes. A subjective evacuation attitude appears to have made the participants more predisposed to a particular behaviour, but individual agency can mean behaviour remains somewhat unpredictable. Evacuation is probably also affected by subjective norms and social networks (Taylor et al., 2009) which is explored in the following chapter. Nonetheless it can be seen from this small sample, most Citizens and all Pragmatists evacuated, while most Individualists and Believers stayed and weathered the storm.

Table 5.14: Evacuation rate for each subjective evacuation attitude

Attitude	Pure loadings	Evacuated	Stayed
Citizen	19	17 (89%)	2 (11%)
Individualist	8	3 (37%)	5 (63%)
Pragmatist	4	4 (100%)	0 (0%)
Believer	5	2 (40%)	3 (60%)

Whilst on the whole it can be seen that most participants loading as Citizens or Pragmatists evacuated, there are some key differences in both their subjective attitudes to hurricanes and evacuation and their actual evacuation behaviour. The evacuation decision of Citizens tended to be influenced more by evacuation warnings by the media and city officials. Almost half of the participants interviewed for the Q study loaded as Citizens, and the vast majority of them evacuated. The two who did

not evacuate wanted to, but could not. This suggests that the evacuation policy of the City of Galveston works for a significant part of the community, as they appear to trust the authorities in their judgement as to whether, and when it is necessary to evacuate. However not all of the Citizens evacuated due to the warnings of the authorities; some of them seemed to evacuate as it is their usual response to a hazardous situation, or they were responding to what they had seen during Hurricane Katrina three years previously. For policy makers, the Citizen is the correct and "rational" attitude for the population to hold; this is evidenced by the fact that three Galveston City officials were shown to identify as Citizens.

Each of the four Pragmatists evacuated. In contrast to the Citizens they were not so motivated by the authorities and official warnings. They tended to make up their own mind about if and when they, their family and property would be at risk and then made the decision to evacuate. These differences resulted in earlier average evacuation times for evacuating Citizens (approximately 38 hours before landfall) compared to Pragmatists (approximately 29 hours before landfall). Again it can be said the existence of the Pragmatists supports the City of Galveston evacuation policy, as these residents interpreted risk information and then made the decision to leave. However, the fact that all of the Pragmatists were Caucasian and well educated suggests that this might be an attitude that is not adopted by all sectors of the community.

Although on the whole Individualists and Believers stayed and weathered the storm, their reasons for doing so were vastly different. Some of the Individualists do not evacuate as a rule and some believed that they were not at risk as they favoured their own judgement over that of the experts and city officials, who are believed to exaggerate the risk. Some of the Individualists also believed that they were sufficiently prepared to live through the hurricane and its aftermath unscathed. This turned out to be true as most of the non-evacuating Individualists did not have cause to regret their decision. This could be because they were used to staying for a hurricane. Because the Individualists were in the main informed of the hurricane, and as a group are relatively wealthy and educated it appears unlikely they did not evacuate because they do not

understand the risk or cannot leave; instead it was generally a positive, agential choice. As such existing evacuation policies concentrating on risk communication and evacuation assistance do not encourage Individualists to evacuate. However, it is interesting to note that the Individualists who did evacuate were influenced by their family.

There were two main reasons why the Believers stayed and weathered the storm. They were either motivated by the belief that a higher power would protect them, or that they would be required to help out those less able to help themselves in the aftermath of landfall. For this reason it would seem debateable that residents with the attitude of a Believer will be affected by the existing evacuation policies of the City of Galveston, as it will be difficult to overcome these spiritual or moral beliefs. The two Believers who did not evacuate also had faith in God, but for them this did not translate in a desire to stay, but to evacuate. Therefore religious faith does not necessarily lead to non-evacuation. Another difference between the Individualists and the Believers was their ethnicity. Whilst seven out of the eight Individualists were Caucasian or Italian, all of the five Believers were an ethnic minority. Therefore it is possible that there are some underlying structural factors which make ethnic minorities more likely to hold the attitudes of Believers, and so less likely to evacuate. One of the non-evacuating Believers stayed and worked in his job in security. Although he claims he could have left if he had wanted, it seems possible he was under pressure not to evacuate.

5.13 Conclusion

The Q study demonstrates a plurality of subjective evacuation attitudes. These differentiated attitudes can result in unexpected and unwanted hurricane evacuation decisions from the perspective of policy makers. While participants associated with two of the four attitudes revealed were likely to evacuate due to a respect for authority and the participants' risk adverse judgement, those associated with the remaining two attitudes were likely to stay and weather the storm due to what policy makers might view as risk seeking or fatalistic attitudes.

There was consensus among the four subjective evacuation attitudes on statement 11; reflecting the belief that participants' evacuation decisions were not influenced by others. In fact it is the 2 groups who were more likely to evacuate who seem to claim they are impacted less by their peers. Perhaps this reflects the theory that people are unaware of the influence of others on their decisions (Christensen and Ruch, 1980). The following chapter is another empirical section which will document the design and running of an agent based model designed to investigate this phenomenon. It documents how the findings from the Q study were used to parameterise the model which is designed to simulate society level evacuation for Galveston Island. Having established the existence of these subjective evacuation attitudes, each factor revealed in the Q study will be used to create a group of agents for the model.

Chapter 6: Investigating Community Level Evacuation

6.1 Introduction

This second empirical chapter builds on the Q study described in the previous section and concerns the design and use of an agent based model (ABM). The ABM was used to investigate the impact of subjective evacuation attitudes and subjective norms (communicated through social networks) on community level evacuation behaviour in Galveston for Hurricane Ike. The Q study unveiled four subjective evacuation attitudes for residents in Galveston for Hurricane Ike; the evacuation results for the participants loading as each attitude are displayed in table 5.14. Because only one of the subjective evacuation attitudes revealed in the Q study presented homogeneous evacuation behaviour, it is clear evacuation is not a direct function of evacuation attitude. As the theory of reasoned action (TRA) explains, attitudes do not correlate exactly with intentions to act; subjective norms also impact on intentions as members of a peer group influence decisions (Fishbein and Ajzen, 1975). This chapter describes the design of an ABM in which each agent is assumed to have a subjective evacuation attitude, based on those revealed in the Q study. The probability that an agent with a particular subjective evacuation attitude evacuates changes according to the time of day, and due to the influence of real life events such as hurricane warnings and environmental cues. Moreover, agents not only evacuate as a result of their subjective evacuation attitude, but also due to the influence of subjective norms.

The research questions addressed in this chapter are the following:

> 2.a. How do different subjective evacuation attitudes combine with subjective norms to create large scale patterns in hurricane evacuation?

2.b. How might changes in subjective evacuation attitudes, subjective norms and social networks alter large scale patterns in hurricane evacuation?

To answer research question 2.a., the Galveston Evacuation Model (GEM) was built to replicate the evacuation behaviour of residents of Galveston in the days leading up to the landfall of Hurricane Ike. The use of the GEM enabled the scaling up of the findings from the Q study, to investigate the impact of these subjective evacuation attitudes at the level of the community. As the framework suggests (figure 4.1), it is also necessary to consider the role of subjective norms, which are communicated through social networks (Wynne, 1989). The TRA postulates that subjective norms have an influence on actions as if a person thinks their significant others favour a specific action, or that a particular action will be viewed positively, they are more likely carry out said action (Fishbein and Ajzen, 1975). Comparatively little work has been undertaken on the impact of subjective norms and social networks on the evacuation decision, although it is increasingly becoming accepted that evacuation behaviour should be understood as collectivistic. For example, in a study by Lindell (2005), peers and networks were deemed to be of more importance than the media when making evacuation decisions, while research on Hurricane Katrina found that 52% of participants citied interpersonal sources as the most important at the time of the evacuation (Taylor et al., 2009).

As the methodological chapter argued, assessing and quantifying the impact of subjective norms and social networks is problematic. Neither traditional qualitative nor quantitative methods can overcome the challenge that people are generally unaware of the impact of others on their decisions (Christensen and Ruch 1980). Traditional modelling approaches are not suited to simulating the impact of social networks as they cannot simulate emergence, or unpredictable behaviour not written into the model which is inherent in social behaviour (Macal and North, 2010). For this study an ABM is used as a research tool which is specifically created for the study of social interaction.

ABMs have been used to simulate evacuation traffic flows (Chen 2008; Zhang et al. 2009; Huang et al., 2012; Mesa-Arango et al., 2013), but ABMs which seek to

investigate evacuation decision making are still rare. The literature review highlighted one particular model which has attempted to simulate the impact of social networks on the decision to leave (Widener et al., 2013). The present study builds on this niche in the academic literature instigated by Widener et al., by developing the methodological basis for an ABM. In contrast to the Widener et al. model, which simulates a theoretical hurricane, the GEM is conceptually different as it uses empirical data to build the model. The GEM uses empirical data on the timing of evacuation from a survey (Van Zandt, 2010) and the interviews conducted at the time of the Q study. It also incorporates the subjective evacuation attitudes from the Q study documented in the previous chapter. As a result it factors in the impact of the mandatory evacuation order and the arrival of the forerunner surge on the evacuation of agents with different subjective evacuation attitudes. This way of designing the model embraces the TRA and shows the effect of differences in attitudes on behaviour (Fishbein and Ajzen, 1975). Furthermore, the GEM uses a different way of simulating the impact of subjective norms. Widener et al. use a threshold approach, meaning that when a critical mass of evacuating members of an agent's social network is reached, the agent is compelled to evacuate. The GEM uses probability to determine whether a resident is persuaded to leave due to peer pressure from subjective norms communicated through the social network. Therefore due to the use of empirical data and the probabilities used to model persuasion, the GEM recognises more subjectivity and agency.

6.2 The shape of hurricane evacuation curves

Although using an ABM to simulate evacuation flow is a novel field, evacuation modelling using mathematical tools is fairly well developed. Whether using a logit based model (Pel et al., 2011), social contagion model (Hasan et al., 2012) or ABM (Widener et al., 2013), when plotted against time, the conventional shape of a cumulative evacuation curve is typically assumed to be s-shaped (Czajkowski 2011). This shape, also known as a Sigmoid curve has been shown to represent many social processes from diffusion of technology to population growth. The Sigmoid curve is flat at the two ends and steep in the middle (figure 6.2). It has an initially slow evacuation

rate which accelerates as the threat is deemed more likely or imminent, before decelerating as the majority of evacuators have already left. Sigmoid evacuation curves have been critiqued by Fu and Wilmot (2004) as they do not factor in variation caused by time of day and tend to cover an insufficient length of time overall. This means they do not reflect reality, assuming a 'time independent continuous process' of evacuation (Yazici and Ozbay 2008, p.762). According to Dow and Cutter (2002), the majority of evacuators leave in the daytime in the 2 days before landfall, which suggests a more complex shaped evacuation curve. Furthermore, it is thought that evacuation decisions are affected by warnings such as evacuation orders and environmental cues such as changes in the weather (Lindell et al., 2005). A Sigmoid curve is therefore rather a crude approach to modelling evacuation as it discounts some of the temporal and behavioural nuances of individual hurricanes and evacuation policies. Despite these shortcomings, Sigmoid curves are still the default shape used in evacuation models which are designed to assist policy makers such as MASSVAC (Hobeika and Jamei, 1985).

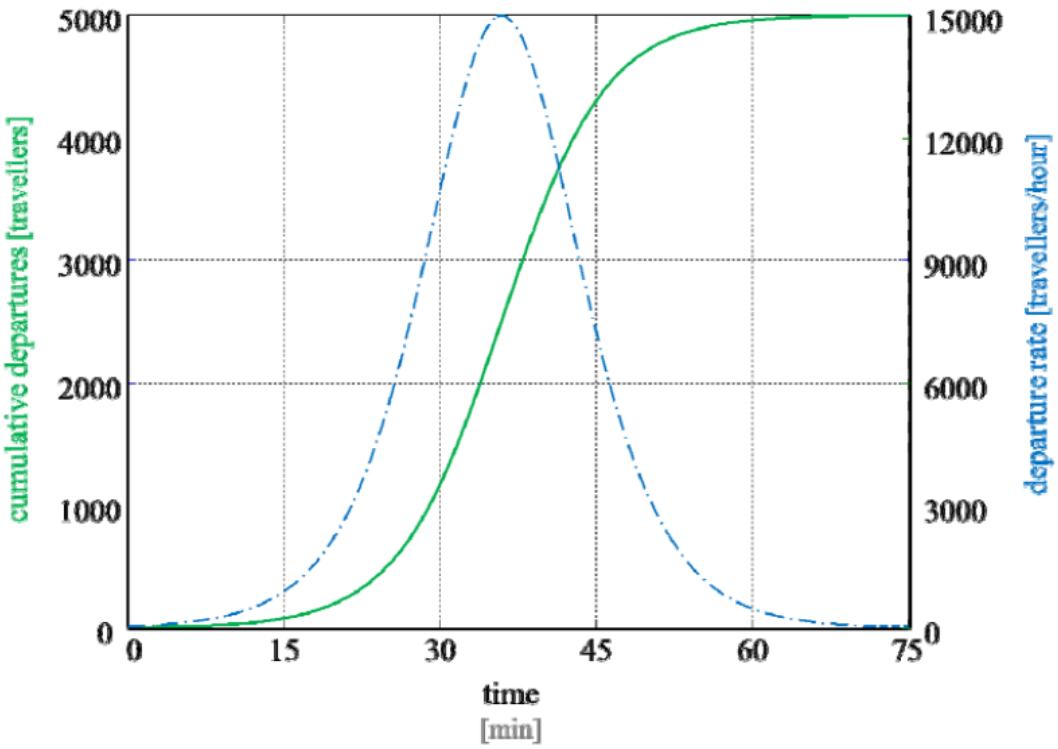

Figure 6.1: A Sigmoid or "s-shaped" evacuation curve. (Pel et al., 2011)**.**

6.3 The calibration data

As the unit of measurement for the Q study was the individual, for the GEM, the unit of measurement is also the individual. In order to accurately calibrate the GEM, a survey on the evacuation of Galveston households was used (Van Zandt, 2010). The data on evacuation which was collected whilst conducting the Q study suggested that the vast majority of households had only one evacuation result. Therefore the survey of household evacuation was considered as a very close proxy for individual evacuation. The survey covered Galveston County, but the data was filtered to include only households on Galveston Island who were at home in the days leading up to the landfall of Hurricane Ike. This meant that there were 418 relevant households, 296 of which evacuated; an evacuation result of 70.8%. For each of the respondents the data used was whether they evacuated, and if so on which day and at what time they left home. Some respondents were unable to give a precise time for when they left, stating they evacuated “in the morning” or “in the afternoon”. These timings were coded as leaving at 10am and 4pm respectively. For those respondents answering with just a date, the time of evacuation was assumed to be 12pm. Evacuation times were rounded to the nearest hour.

The evacuation graph for the calibration data is shown in figure 6.2. The graph shares some of the properties of a Sigmoid curve, as the curve is flat at the beginning of the process, and has a shallow rate of increase for the first two days. On the morning of the 10th of September, the rate increases and then levels out again as night approaches. This pattern is repeated in the day of the 11th and 12th, before the graph levels out for a final time on the evening of the 12th. At this point pre-landfall evacuation became impossible as the roads were flooded. In the periods between the peak morning evacuation flows, there are periods of slower flows. It was therefore decided to design the GEM in order to replicate the double s-shaped curve of the calibration data.

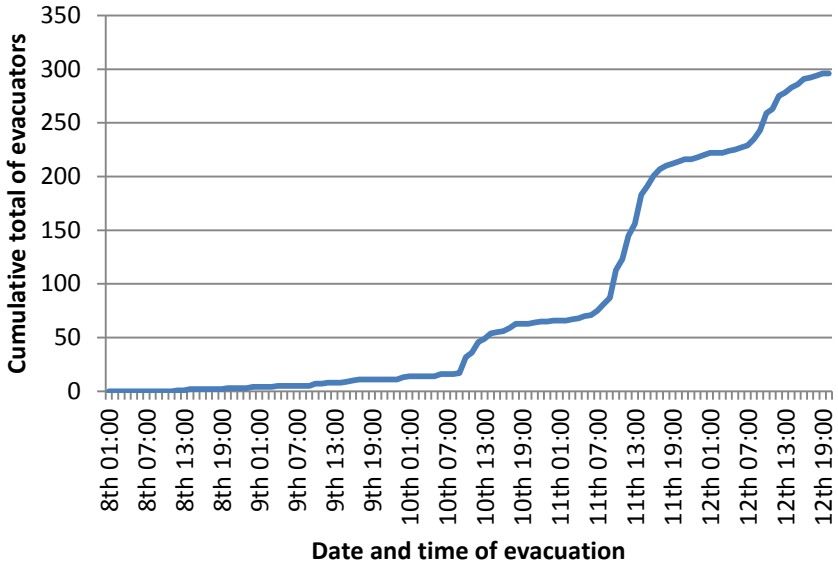

Figure 6.2: The double s-shaped evacuation curve of the calibration data. Adapted from Van Zandt (2010).

6.4 The selection of software and design of the GEM

There are numerous programmes available for the creation of ABMs, which vary in accessibility and programming language. For this study, the tool chosen was AnyLogic developed by XJ Technologies. Anylogic can be used for various simulation methods, such as discrete event and system dynamics in addition to agent based modelling. It has a significant advantage over many of its competitors as it can be coded in Java or graphically, making it user friendly for researchers with limited experience of Java programming. An ABM designed using AnyLogic simulates the interactions of agents in a hypothetical or empirically observed environment and a model typically simulates the transition of agents from one state to another. In the GEM, the agents are people on Galveston who have to make the decision to evacuate or weather the storm as Hurricane Ike approaches the island. Agents therefore move from the state of potential evacuator to evacuator. The transitions are the processes by which evacuators decide to evacuate and are related to subjective evacuation attitudes and subjective norms (figure 6.3). Whether these processes cause individual agents to evacuate depends on events and parameters. The events determine when a process might occur, while the parameter defines the probability of an event resulting in evacuation.

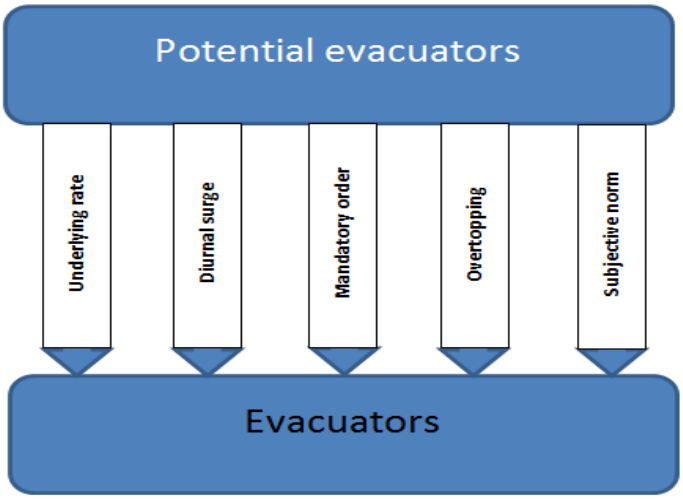

Figure 6.3: The transitions potential evacuators take to evacuate in the GEM

Within agent based modelling there is a balance to be achieved along a spectrum ranging from simplicity to reality. The approach taken in this model is to split the difference. The model uses the real life timings of Hurricane Ike's approach and the responses of the authorities. In addition, empirical data was used as calibration for the timing of the evacuation, and the agents in the model are assumed to hold one of the four subjective evacuation attitudes which were unveiled in the Q study. On the other hand, it was decided to adopt a more theoretical approach to the location of the agents within the model, as they are assumed to be randomly spread throughout the environment they inhabit. The reason for this is that both the Q study and the calibration survey found that many residents of properties protected by the seawall evacuated, while some residents in unprotected properties did not leave, thus suggesting a similar random pattern was reflected in reality.

In the GEM, it is assumed that the binary decision to evacuate or not is made by each agent at hourly intervals until they evacuate or the model runs its course. The days leading up to the landfall of the hurricane are discretised into hourly intervals and coded from hour 1 to hour 116, with hour 1 representing 01:00 on September 8th and hour 116 representing 20:00 on September 12th. It was decided that the beginning of movement off the island to be considered as evacuation was 08:00 on the morning of

September 8th, as before this time very few people left and it was problematic to assume that those who did leave before this time were leaving Galveston primarily in order to evacuate from Hurricane Ike. According to the calibration data, the latest observed household evacuation took place at 19:00 on September 12th. It is likely that this was one of the last journeys of evacuators leaving the island, as roads were largely impassable at that time.

Investigating research question 2.a meant designing the GEM to replicate the double s-shaped curve of the calibration data. In order to build the model it was decided to use as much empirical data as possible. It was decided to populate the model with 3000 agents as this was a manageable number for computation. The model was populated with agents holding the four subjective attitudes revealed in the Q study. Each agent was assigned one of the subjective evacuation attitudes in the approximate proportions in which they arose in the Q study. The number of agents of each type, and the proportion of each type evacuating was converted to a round figure as table 6.1 shows. This resulted in an overall target evacuation rate of 71% for the GEM, approximately the same as the evacuation rate for the calibration data (70.8%).

Table 6.1: Evacuation rates for the Q study and GEM

Agent type	Loadings in Q study	Agents in the GEM	Evacuated in Q study	Evacuators in GEM
Citizen	19 (52.8%)	1500 (50%)	17 (89.5%)	1350 (90%)
Individualist	8 (22.2%)	750 (25%)	3 (37.5%)	300 (40%)
Pragmatist	4 (11.1%)	300 (10%)	4 (100%)	300 (100%)
Believer	5 (13.9%)	450 (15%)	2 (40%)	180 (40%)
Total	36 (100%)	3000 (100%)	26 (72.2%)	2130 (71%)

6.5 The inclusion of the underlying evacuation rate

Building the GEM involved using both empirical findings and theoretical bases to emulate the evacuation curve of the calibration data. Initially, it was necessary to make the agents proactive and behave with an objective (Kniveton et al., 2011). To achieve this, an underlying evacuation rate was included in the model; this is the probability of an agent evacuating each hour. This was found by simply dividing 1 by the number of

hours of the model. From the calibration data, it is assumed that evacuation begins from 08:00 on September 8th; therefore evacuation takes place over 109 hours. This gave a probability of evacuating each hour of 0.00917 (table 6.2). The evacuation result from the underlying probability of evacuating is graphed in figure 6.4 in which the calibration data has been scaled up to represent the evacuation result of 3000 people. The shape of the GEM curve does not correspond to the calibration evacuation curve, as it has a decelerating rate of evacuation; the number of evacuators each hour decreases as the potential number of evacuators decreases. However, it is also clear that the complex double s-shape of the validation data cannot be explained through a crude rate, there must be other factors which also cause evacuation. For this reason the figure for underlying probability of evacuation was then divided by 10, as it was assumed that it would be attributable to only approximately 10% of evacuation. AnyLogic generates random numbers to determine whether a parameter has an impact on a model. Therefore in the GEM, an agent evacuates every hour due to the underlying probability of evacuating if a random number is generated below 0.000917.

Table 6.2: Evacuation result from the underlying rate

Hourly Evacuation Rate	Average Evacuators
0.00917	1901.1 (63.4%)
0.000917	292.8 (9.8%)

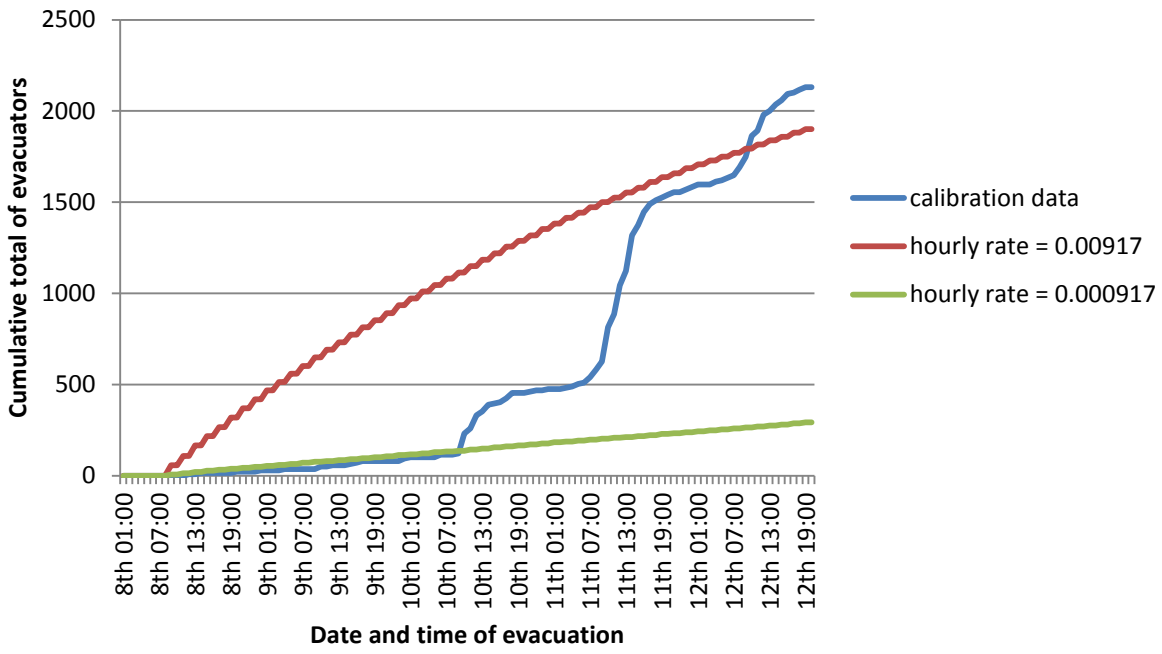

Figure 6.4: The underlying hourly evacuation rate

6.6 The inclusion of the diurnal surge

There are surges which occur in the calibration data which are not reflected in the GEM (fig 6.4). As Fu and Wilmot (2004) state, the double s-shaped evacuation curve is explained by surges in evacuation in daylight hours. Consequently it was decided to include a diurnal surge of evacuation. To decide the probability of evacuation during the day, the calibration data was used to find the average evacuation rate for each hour from 08:00 to 18:00 over the five day period from the 8th to the 12th of September. When the observed data was averaged over 2 hour blocks it closely resembles a normal or bell-shaped curve with a mean of 13:00 and a standard deviation of 3.5 (figure 6.5). Therefore an event was programmed for each agent to increase the probability of evacuating in the daytime. The Q study provided little basis to distinguish between the four agent types in terms of the time of day of evacuation, therefore each was given the same probability of evacuating due to the diurnal surge.

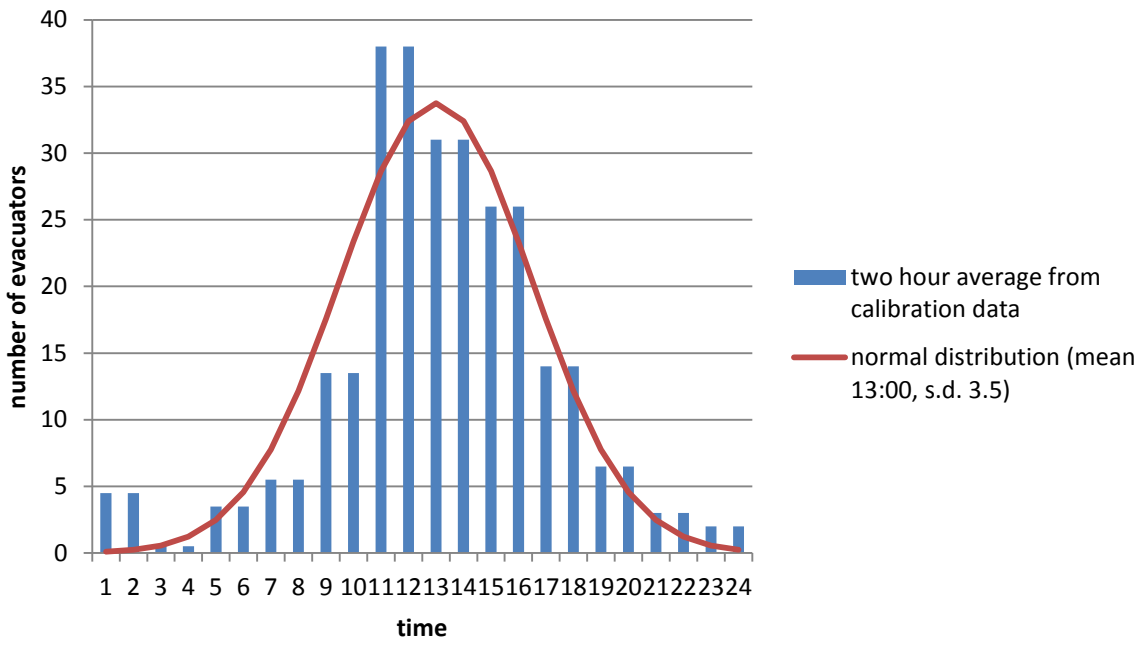

Figure 6.5: The diurnal surge of the calibration data as a normal distribution

Each of the potential evacuators experiences an increased probability to evacuate on September 10th, 11th and 12th. It was decided not to include surges on the 8th and 9th as on these days evacuation was minimal. The diurnal surge was parameterised into the GEM using a probability distribution with the occurrence time "normal(3.5,61)", with 3.5 referring to the standard deviation and 61 referring to the 61st hour of the model (13:00 on September 10th), which is the mean. The diurnal surge was termed cyclical so it repeats every 24 hours. The parameter for the diurnal surge was initially set at 0.1 as it was assumed that the diurnal surge should not account for more than 10% of total evacuation. The parameter was further reduced to 0.09, as the diurnal surge only takes place in the daytime. In this way, the impact of the tails of the distribution, corresponding to evacuation which takes place outside of daylight hours is discounted (table 6.3). The resulting evacuation graph has a double-s shape, although the number of evacuators is still much lower than the calibration data (figure 6.6).

Table 6.3: Evacuation result from the underlying rate plus diurnal surge

Strength of Parameter	Average Evacuators
0.09	947.9 (31.6%)

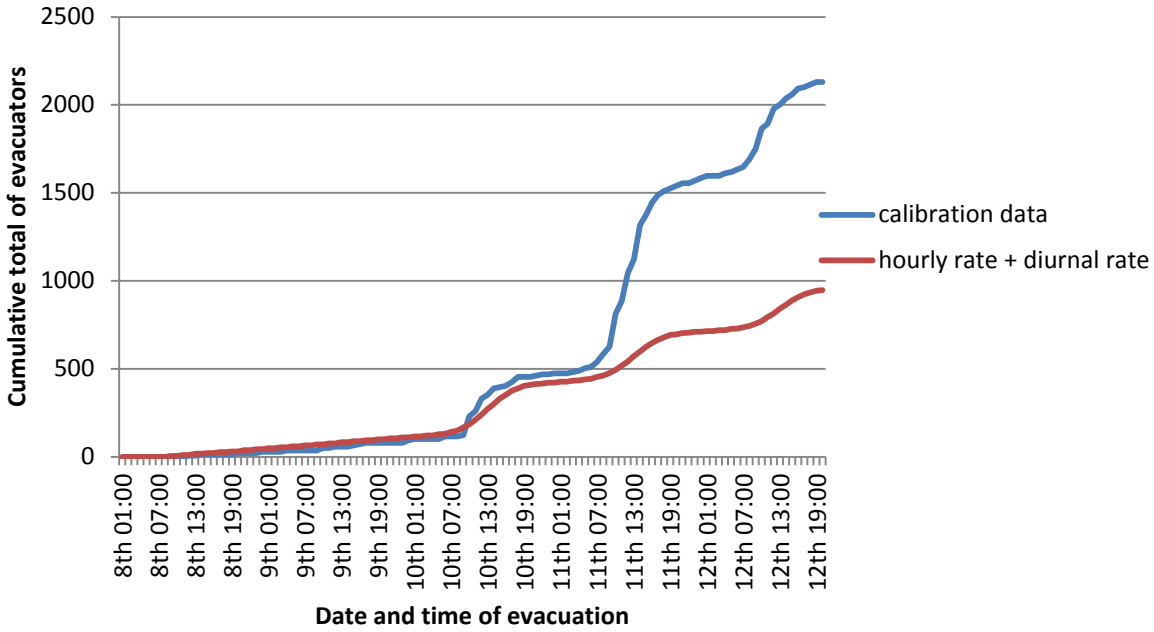

Figure 6.6: The underlying evacuation rate plus diurnal surge

6.7 The inclusion of events

The Q study supported the findings of Gladwin, Gladwin and Peacock (2001) that some residents are likely to be impacted by warnings and environmental cues. According to the framework of the thesis, this would most likely happen due to a change in the threat appraisal affecting the subjective evacuation attitude. This can be simulated by increasing the probability of certain agents evacuating at specific times due to salient events. There are several events which could be considered to be important enough to make agents reactive, and respond to the environment (Kniveton et al., 2011). Whereas the underlying probability to evacuate and the increased probability of leaving in the daytime are based on the calibration data, the probability of evacuating due to events is generated from the Q study and the interviews conducted at the time. It is assumed that the higher evacuation rates for the Citizens and Pragmatists are explained by their subjective evacuation attitudes being more likely to be influenced by events. It is assumed that the lower evacuation rates for the Individualists and Believers are as a result of them not being influenced by events. Therefore the events

are only parameterised for the agents who are identified in the GEM as Citizens and Pragmatists.

It was decided to incorporate two events into the GEM; the mandatory evacuation order which was called on the morning of the September 11th and the overtopping of the seawall which occurred on the afternoon of September 12th. From the Q study, eight of the Citizens who evacuated left on the September 11th, and the same amount said that the mandatory evacuation order influenced them in the decision to leave. Five of the Citizens who evacuated left on September 12th, and two of those reported as being motivated by the threat of the storm surge. Two of the Pragmatists evacuated on the 11th and two evacuated on the 12th. One of the Pragmatists who left on the 11th reported being motivated by the evacuation order and the other had left before the order was issued. Both of the Pragmatists who evacuated on the 12th reported being wary of the storm surge. Although five of the evacuating Citizens left on the 10th, it was decided not to parameterise an event for this day. This is because although the diurnal surge has the same probability for the 10th, 11th and 12th, the effect is stronger on the 10th as the number of potential evacuators is higher. The GEM could just as well have been designed with a diurnal surge on only the 11th and 12th, with an event on the 10th to cover the evacuation surge on this day. Although on the 10th a voluntary evacuation was called for the West End of the island, the Q study did not identify it as an event which may have caused significantly increased levels of evacuation.

It is clear that in reality, residents did not automatically leave as soon as these events occurred. It might take some time for the change in the status quo to be perceived by the residents and even those perceiving a change will not necessarily be able to leave immediately. For this reason it was decided to simulate the impact of each of the events which caused increased evacuation to occur within four hours of the event taking place. It was assumed that most evacuation triggered by the events occurred soon afterwards; therefore the probability distribution chosen was triangular. This distribution has a minimum and maximum point, and a tail towards the right. The mandatory evacuation order was given at 09:30 on September 11th, so the related evacuation is parameterised as “triangular(82, 86, 82)”. This means it occurs between

10:00 and 14:00 on September 11th, with 10:00 also being the mode. Overtopping actually occurred at 15:00 on September 12th, but as the sea level was rising all morning and flooding on the West End of the island was occurring from the morning, it is parameterised as “triangular(105, 109, 105)”, meaning it occurs between 09:00 and 13:00 on the 12th, with 09:00 also being the mode.

As the proportion of both Citizens and Pragmatists who evacuated on the 11th September was approximately 50%, in the GEM it is assumed that Citizens and Pragmatists have the same probability of evacuating for the mandatory evacuation order. According to the Q study and interviews, 50% of evacuating Pragmatists left on September 12th, while only approximately 30% of evacuating Citizens left on that day. Therefore it is assumed that in the GEM the parameter for overtopping will be stronger for the Pragmatists. As these results came from a small number of participants it is necessary to use optimisation, or a sensitivity test to find the exact parameters to produce an evacuation result similar to the calibration data (table 6.4). It was decided to begin with a probability of 0.5 for Citizens evacuating due to the mandatory evacuation order and the overtopping of the seawall, and 0.5 for Pragmatists evacuating due to the mandatory evacuation order and 0.9 for the overtopping of the seawall.

Table 6.4: Sensitivity test for the parameterisation of events

Event run	Citizen Mandatory	Citizen Overtopping	Pragmatist Mandatory	Pragmatist Overtopping	Evacuation Result
1	0.5	0.5	0.5	0.9	1915.6 (63.9%)
2	0.75	0.75	0.75	0.9	2109 (70.3%)
3	0.65	0.65	0.65	0.9	2053.1 (68.4%)
4	0.625	0.625	0.625	0.9	2016.3 (67.2%)
5	0.6	0.6	0.6	0.9	2005.6 (66.9%)

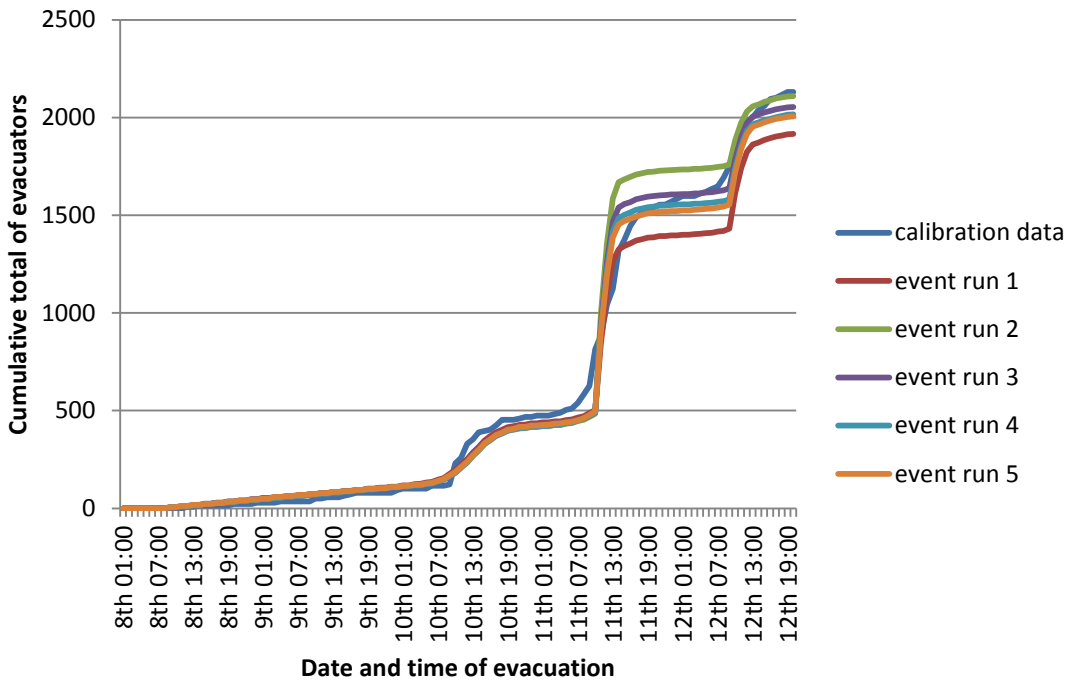

Figure 6.7: Evacuation curves for varied parameterisation of events

As figure 6.7 shows, event run 1 did not result in sufficient evacuation, while event run 2 resulted in too much evacuation. In event run 3, the impact of the mandatory evacuation order was too strong compared to the impact of the overtopping of the seawall. Event run 4 was very close to the calibration data, but did not sufficiently match the evacuation timings for Pragmatists revealed in the Q study. Event run 5 closely matched the validation data, but was also consistent with the evacuation timings from the Q study. As a result, event run 5 was selected as the most suitable parameterisation for the GEM (figure 6.8).

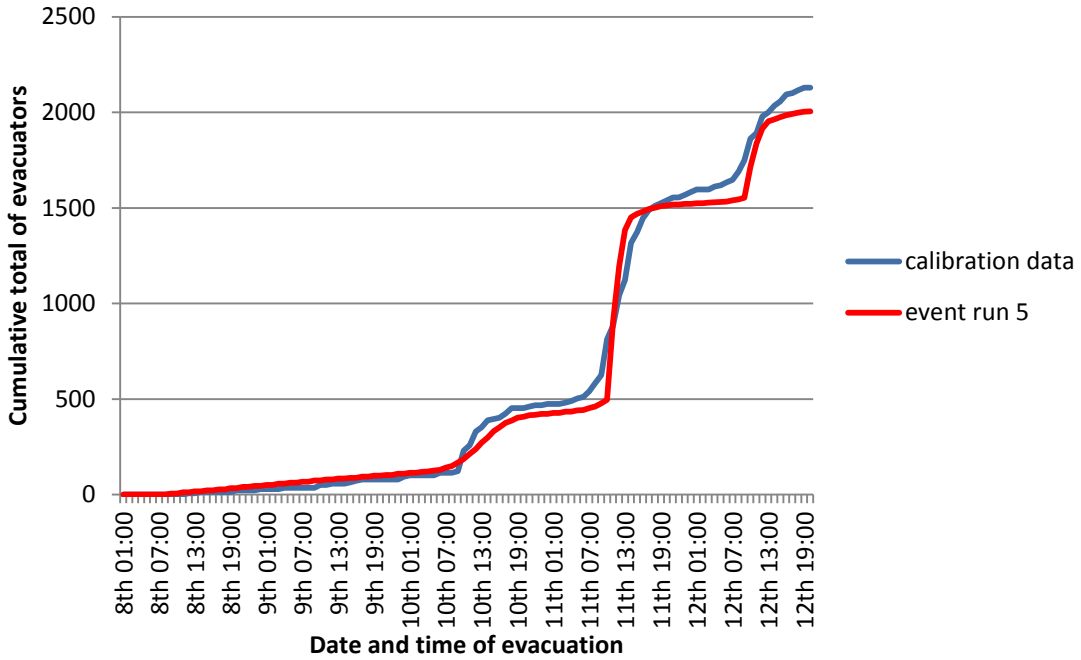

Figure 6.8: The underlying evacuation rate plus diurnal surge plus events

6.8 The inclusion of a social network and subjective norm

Although the GEM was now closer to representing the evacuation result of the calibration data, the evacuation graph of the GEM was characterised by a line which was more angular than the calibration data, meaning the flow of evacuation was too discrete, and occurring in steps (fig 6.8). Although the surges were effectively mirrored, the rounded ends of each surge did not appear in the GEM. One explanation for this divergence could be the impact of subjective norms were not included in the GEM. The final stage in the development of the GEM was to incorporate this theoretical consideration into the GEM and give the agents sociability; the ability to interact (Kniveton et al., 2011). Although it is difficult to quantify the impact of subjective norms on the decision to evacuate, the interviews which followed the Q study suggested that members of the social network had a genuine influence. Out of the twenty six evacuators in the Q study, twenty two reported having been influenced by family members, while nine said that they had been influenced by friends. No data was gleaned concerning the size and type of social network to which the participants belonged. The difficulties of obtaining such data have been highlighted by Hasan

(2012), who asserts that it is problematic to empirically observe social networks. Instead the GEM was used to perform a sensitivity test and quantify the impact of subjective norms. This was done by assuming that the subjective norm is to evacuate; that is peer group pressure is manifested as an increased probability of evacuation.

It is assumed that there are no differences in the social networks to which each of the four agent types belong. As all of the agents live on the island of Galveston, they are modelled as inhabiting the same environment with the same social network. Although it could be argued that people are more likely to communicate with others who share similar outlooks, it is assumed that networks cut across the four subjective evacuation attitudes. There has been some research on the impact of the number of contacts which an individual has on the decision to evacuate. It has been found that the more contacts one has, the more likely one is to receive recommendations to evacuate (Perry, 1979) and those who do not evacuate tend to have smaller social networks (Drabek and Boggs, 1968). Although it is possible residents loading on some subjective construct might have smaller networks than those loading on others, this was not something which was ascertained from the Q study or interviews. Therefore for the GEM it is assumed each agent has the same number of people in their network.

This means in the GEM the important variable is not necessarily how many people are in the agent's network, but rather how the network is able to influence the agent, in contrast to Widener et al.'s (2013) threshold or tipping point method. In the GEM, the number of agents in your network who have evacuated influences the decision to leave, not through reaching a threshold, but due to an increased probability that the message to leave will be acted upon. The subjective norm impacts the model through all evacuating agents applying peer pressure on members of their social network by sending a message advising evacuation. Messages encouraging evacuation are acted upon if the random number generator produces a number less than the receiving agent's suggestibility to influence. In this way a tipping point can also be reached; not through a direct function of the evacuation decision of the other nodes in the network, but through the increase in the quantity of messages which an agent receives. This means that the more members of an agent's network evacuate, the more likely an

agent is to leave. This is not because the agent reaches a threshold after which the weight of influence baring down upon him means he feels compelled to leave, but rather through receiving more messages suggesting he leave, he has more opportunities to be convinced that evacuation is the best decision. The advantage of this method of modelling the influence of peer pressure is that the importance of the influence of the peer group is recognised, whilst the individual agency of each decision maker is retained. Therefore the model assumes that whilst the social network should have an influence over evacuation decisions; it should not automatically overrule the subjective attitude towards evacuation.

The GEM stipulates that if an agent does not evacuate he does not send a message, but every time an agent leaves he communicates with the members of his social network to tell them they too should leave. It is supposed this communication could take the form of witnessing neighbours evacuating, having a face to face conversation, making a phone call, or writing a text message or social media post. It is assumed that it will take some time for the message to be communicated by the evacuator, or received by members of the social network. For instance, an evacuator might make a phone call only after he is clear of the island and heading inland, and a text message, email, social media post or voicemail might not be received immediately. Moreover it takes time to prepare for evacuation; this includes returning home from work, packing and securing the home. In a study of over five hundred residents on the Gulf Coast, it was found that the mean amount of time needed to prepare for evacuation was 229.9 minutes (Lindell et al., 2001). Therefore in the GEM, preparation time after network communication is set at four hours. This is manifested through the use of a “delay” tool which makes agents only act on messages received through the social network after four hours.

For the creation of the GEM it was decided to assume a small world network and a social network size of 5. The small world represents a community mostly defined by neighbourhood. It is assumed that most communication is local, with some global communication, which could be through telecommunications or social media. Research has shown that small world networks exist in real life. (Watts and Strogatz,

1998). In order to optimise the small world network it was necessary to find a parameterisation which would approximately match the evacuation result of the calibration data. Parameterisation for a small world network is complicated as network size and neighbour link fraction need to be considered. The latter ranges from 0 to 1 and determines the proportion of the peer group who are situated locally to the agent. A neighbour link fraction of 0.8 was used, meaning 80% of an agent's connections are located nearby. This meant that for a network size of five, four of the agents were located in the neighbourhood and one was located elsewhere on the island at random. The size of the social network was set at five, as the modal number of core discussion ties for residents of the USA (Hampton et al., 2011). Although this survey revealed the mean number of core discussion ties was two, the authors believe that the participants did not include those ties with whom they do not have regular face to face contact, nor did it include ties deemed to be significant but not core discussion ties. In the context of an approaching hurricane it is assumed that people will communicate with members of their core network through technology, and will communicate with members of their social network with whom they might not usually discuss decisions as increased risk creates a fluid and evolving network (Kossinets and Watts, 2006). Therefore it was decided to use the higher number of five contacts for the GEM.

In order to replicate the calibration data, it was decided to perform a sensitivity test for the strength of the subjective norm. As before the network was introduced, the GEM was already approximating the calibration data, it was assumed that the impact of the subjective norm is quite low. As such, the strength of the subjective norm was parameterised as 0.01. Therefore if a random number is generated below that of the subjective norm, it is assumed that the evacuating agent succeeds in convincing the receiving agent to evacuate. As each evacuating agent sends a message to each of the agents in his network, the number of evacuations caused by subjective norms increases after evacuation surges occur. This effect diminishes as the model runs its course, as an increasing number of receiving agents have already evacuated. When the subjective norm is parameterised as 0.01, a maximum of approximately 5% of remaining agents are expected to evacuate, while for 0.1 a maximum of approximately 50% of remaining agents are expected to evacuate. The parameter for the subjective

norm was optimised by beginning at 0.01 going up in increments of 0.01, until the GEM matched the calibration data as closely as possible (table 6.5). It was only necessary to run the model five times before the GEM closely matched the calibration data.

Table 6.5: Sensitivity test for the parameterisation of subjective norms

Opinion Leader	Evacuation result
No network	2005.6 (66.9%)
0.01	2030.3 (67.7%)
0.02	2056.3 (68.5%)
0.03	2073.7 (69.1%)
0.04	2103.8 (70.1%)
0.05	2125.6 (70.9%)
Calibration data	2124.4 (70.8%)

As figure 6.9 shows, through using heterogeneous agents and with consideration of agents' proactivity, reactivity and sociability, the GEM approximately reproduces the shape of the calibration data. As such it can be argued that the GEM effectively simulates the evacuation result and timing of Galveston Island in the lead up to Hurricane Ike. Through modelling the agents as holders of one of the four subjective evacuation attitudes unveiled in the Q study, and the probabilistic simulation of the impact of subjective norm, the GEM also recognises a great deal of individual agency and subjectivity.

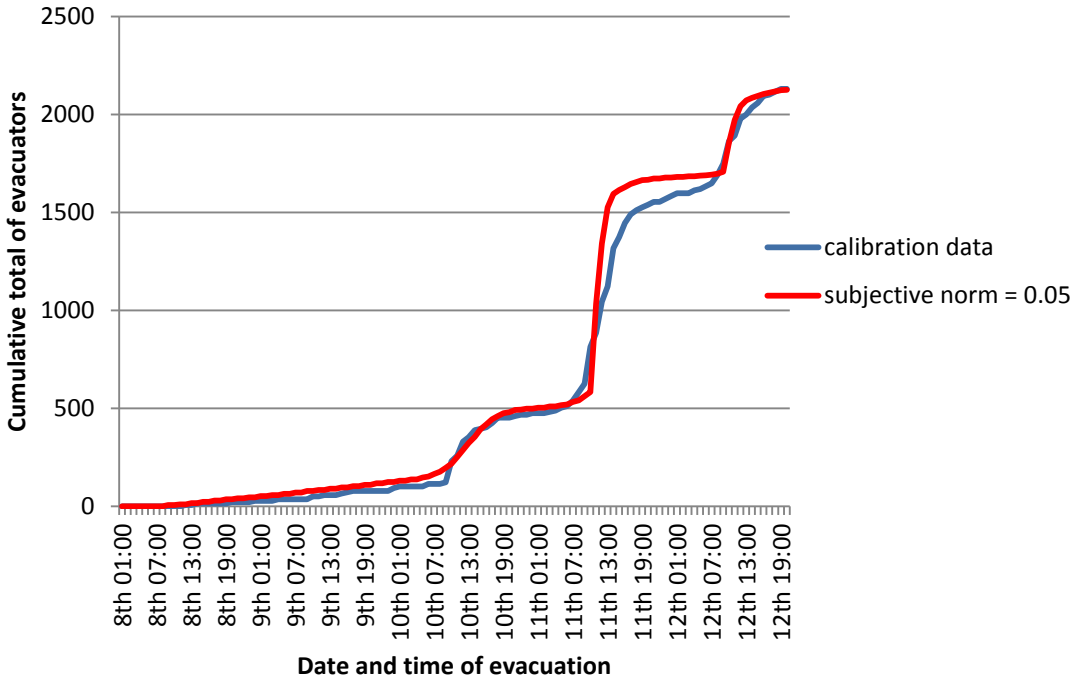

Figure 6.9: The evacuation curves of the GEM and the calibration data

6.9 The influence of subjective evacuation attitudes

In order to answer research question 2.a, further experiments were then performed on the default GEM. Petty et al. (1997) claim that attitudes are not permanent, but rather can evolve. In the GEM the probability of evacuation changes according to the time of day, warnings from officials and environmental cues. Through policy or other means, it might also be possible that residents adhering to one of the subjective evacuation attitudes revealed in the Q study take on one of the other hurricane evacuation attitudes or evacuation results. How this might occur is briefly addressed in the following chapter, but it could be assumed that this might mean more residents identify as Citizens and Pragmatists, while less residents identify as Individualists and Believers. By altering the relative populations of each subjective hurricane attitude in the model, new island-level evacuation results can be generated. In order to examine the effect of a change in subjective hurricane attitudes, it was decided to run the GEM with the same parameters as the default model, but to change the proportion of

residents assumed to hold each of the four subjective evacuation attitudes unveiled in the Q study.

Table 6.6 shows the original proportions of each attitude type in the default model. In the variation of the default model, the proportion of the Citizens rises while the proportion of Believers falls. At the same time, the proportion of Pragmatists rises while the proportion of Individualists falls. As both Citizens and Believers express limited independent agency, it is assumed in future some Believers might adopt the attitudes or evacuation decisions of the Citizens. In a similar way, Pragmatists are related to the Individualists as they both make informed, independent decisions; therefore it could be possible that the next time a hurricane impacts Galveston some of the Individualists might adopt the attitudes or evacuation decisions of the Pragmatists. As table 6.6 shows, as the proportions of Citizens and Pragmatists increase, the number of total evacuators also increases in a linear fashion. Over 75% of the population evacuate under model run 3 and over 87% evacuate under model run 6.

Table 6.6: Sensitivity test for the proportions of subjective evacuation attitudes

Model run	Citizens	Individualists	Pragmatists	Believers	Evacuation Result
1	1500	750	300	450	2125.6 (70.9%)
2	1575	675	375	375	2197.9 (73.3%)
3	1650	600	450	300	2286.2 (76.2%)
4	1725	525	525	225	2384.3 (79.5%)
5	1800	450	600	150	2449.3 (81.6%)
6	1875	375	675	75	2547.8 (84.9%)
7	1950	300	750	0	2627.8 (87.6%)

6.10 The influence of subjective norms and social networks

The GEM also allows the investigation of changes in subjective norms on island-level evacuation. This is simulated through changing the type and size of social network, and the strength of the subjective norm. It is possible that subjective norms could evolve over time (Kossinets and Watts, 2006). This could mean that in the future staying and weathering the storm could be considered less acceptable by the island community. As

a result of the deaths, injuries and difficult aftermath of staying on the island during Hurricane Ike, the next time that a hurricane is predicted to make landfall it is likely that residents will be subjected to more intense peer pressure from members of their social network imploring them to leave. Policy makers and practitioners might also proactively engage with the community to promote pro-evacuation messaging via key social networks. In the GEM this can be simulated by altering the strength of the subjective norm which represents the messages agents receive encouraging them to leave.

In the last few years, research has shown that people increasingly use social media to communicate both generally, and when impacted by hazards (Sakaki et al., 2010; Vieweg et al., 2010; Crowe, 2011). This suggests that the size of social networks are increasing, and as people have ever more contact with their peers, it is likely that decisions are becoming more affected by their significant others. Below, the size of the social network in the GEM is increased to investigate the impact of technological developments and diffusion. The GEM can also test the impact of the way in which a social network is organised. AnyLogic permits the modelling of 5 distinct network types. There are two networks which connect agents based on their proximity. A distance-based network connects an agent to all other agents within a given distance, while a ring lattice network connects agents to a fixed number of agents who are situated nearby. These network types would are suited to modelling a more traditional community, without the use of telecommunications. A simulation of the 1900 Great Storm might use one of these networks, but for Hurricane Ike in 2008, they are not appropriate. In addition to the small world network used in the default GEM, two other types of networks; random and scale free are instead tested in the following section. In these runs of the GEM, the parameterisation of the networks is altered by simultaneously altering the size of the network and the strength of the subjective norm. This was done for each of the three selected network types. The other parameters are assumed not to have changed. A sensitivity test was carried out increasing the size of the network from 5, and the strength of the subjective norm from 0.04.

The first network to be sensitivity tested was the small world network (table 6.7). As figure 6.11 shows, both the size of the network and the strength of the subjective norm impact positively on the macro level evacuation result, with approximately 75% evacuation achieved with a network size of 7 and a subjective norm of 0.1, or a network size of 8 and a subjective norm of 0.08.

Table 6.7: Sensitivity test for the small world network

Network size	Subjective norm	Evacuation result
5	0.04	2103.8 (70.1%)
5	0.06	2151 (71.7%)
5	0.08	2174.1 (72.5%)
5	0.1	2218.6 (74%)
6	0.04	2107.6 (70.2%)
6	0.06	2158.5 (72%)
6	0.08	2181.8 (72.7%)
6	0.1	2219.3 (74%)
7	0.04	2120.4 (70.7%)
7	0.06	2174.6 (72.5%)
7	0.08	2227 (74.2%)
7	0.1	2257 (75.2%)
8	0.04	2131.3 (71%)
8	0.06	2182.7 (72.8%)
8	0.08	2247.4 (74.9%)
8	0.1	2273.1 (75.8%)
9	0.04	2146.4 (71.5%)
9	0.06	2214 (73.8%)
9	0.08	2270.7 (75.7%)
9	0.1	2330.4 (77.7%)
10	0.04	2152.8 (71.8%)
10	0.06	2232.8 (74.4%)
10	0.08	2285.7 (76.2%)
10	0.1	2308.4 (76.9%)

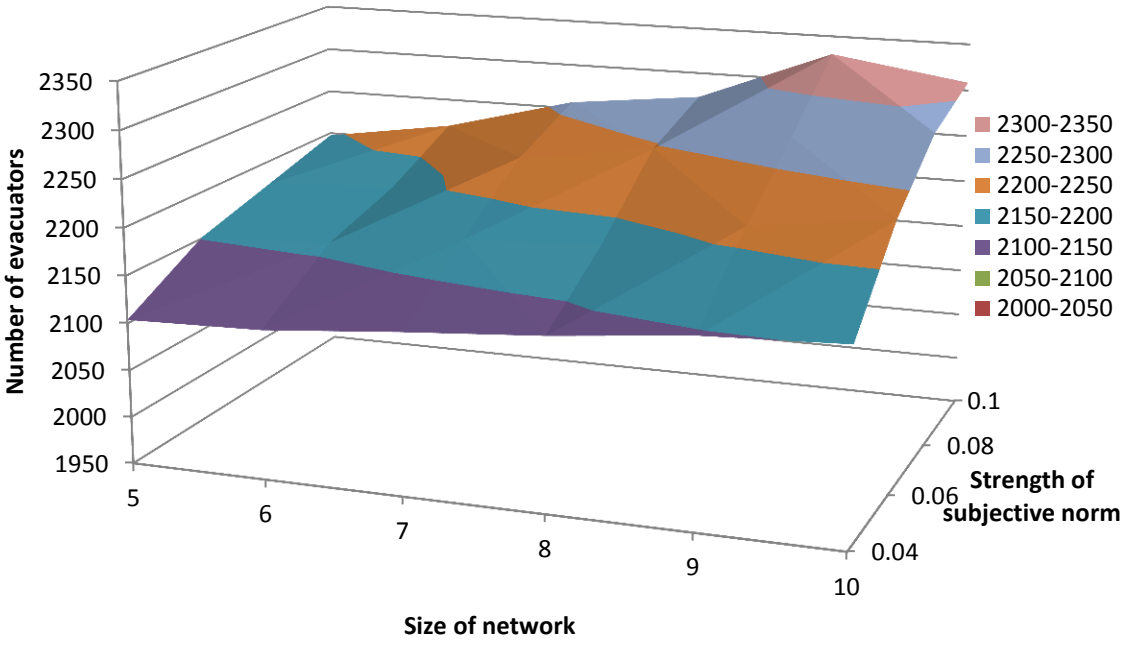

Figure 6.10: The effect of changes in size of network and strength of subjective norm in a small world network

In a random network, the nodes which an agent are connected to are decided at random; some of them are close while others are further away. A sensitivity test was performed in the same way as for the small world network (table 6.8). Figure 6.12 depicts in three dimensions the effect of changes in both the size of the network and the strength of the subjective norm on the evacuation result. Both the number of households in the network and the strength of the subjective norm impact positively on the macro level evacuation result, with approximately 75% evacuation achieved with a network size of 8 and a subjective norm of 0.06, or with a network size of 6 and a subjective norm of 0.08.

Table 6.8: Sensitivity test for the random network

Network size	Subjective norm	Evacuation result
5	0.04	2125.6 (70.9%)
5	0.06	2185.7 (72.9%)
5	0.08	2216.6 (73.9%)
5	0.1	2269.9 (75.7%)
6	0.04	2136 (71.2%)
6	0.06	2207.9 (73.6%)
6	0.08	2248.5 (75%)
6	0.1	2298.2 (76.6%)
7	0.04	2177.1 (72.6%)
7	0.06	2225.4 (74.2%)
7	0.08	2293.4 (76.4%)
7	0.1	2332.7 (77.8%)
8	0.04	2169 (72.3%)
8	0.06	2259.6 (75.3%)
8	0.08	2319.3 (77.3%)
8	0.1	2349.7 (78.3%)
9	0.04	2202.1 (73.4%)
9	0.06	2294.1 (76.5%)
9	0.08	2329.6 (77.7%)
9	0.1	2389.4 (79.6%)
10	0.04	2212.1 (73.7%)
10	0.06	2301.3 (76.7%)
10	0.08	2363.3 (78.8%)
10	0.1	2411.4 (80.4%)

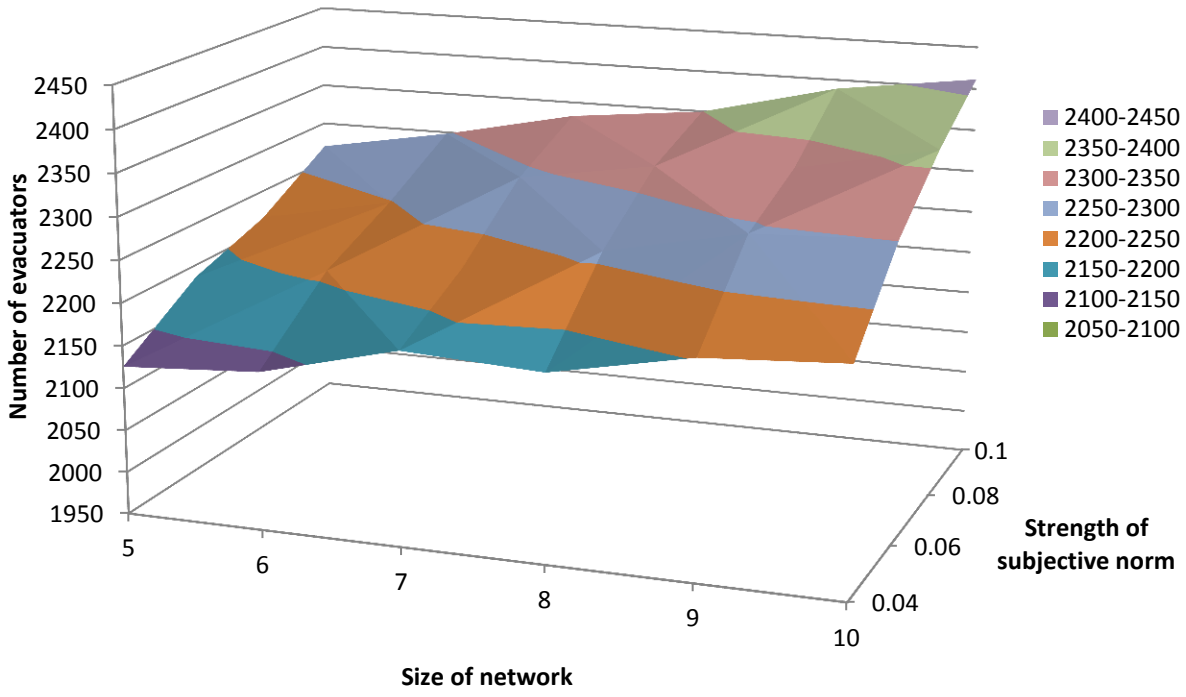

Figure 6.11: The effect of changes in size of network and strength of subjective norm in a random network

AnyLogic also allows for the design of a scale free social network, which simulates a network in which most of the agents are connected at random to a fixed number of other agents. However, there is a crucial difference between the scale free and random networks. In the former, a small number of agents act as hubs and have more connections, meaning the scale free network can capture variability within a social network which a small world or random network cannot. This type of network can be used to simulate the concept of "Opinion Leaders" who have a larger social circle than average (Taylor 2009). Those nodes who have more contacts than the average resident are both more likely to be influenced, and more likely to influence than other residents. This is why it has been shown that in a scale free population, an epidemic can develop even with low contagiousness (Pastor-Satorras and Vespignani, 2001). To parameterise the scale free network, it is necessary to give a value for "M" which represents the scale of variation in network size. As table 6.10 shows, as M increases, so too does the

total number of evacuations. A 75% evacuation rate is achieved when M is 5, and a subjective norm of 0.08, or M is 7 and a subjective norm of 0.06, or a network size of 10 and a subjective norm of 0.04. An increase in M and strength of the subjective norm causes a linear increase in the evacuation rate (figure 6.13).

Table 6.9: Sensitivity test for the scale free network

M	Subjective norm	Evacuation result
5	0.04	2149.2 (71.6%)
5	0.06	2194.7 (73.2%)
5	0.08	2269.5 (75.7%)
5	0.1	2304.1 (76.8%)
6	0.04	2182.5 (72.8%)
6	0.06	2234 (74.5%)
6	0.08	2280.5 (76%)
6	0.1	2329.2 (77.6%)
7	0.04	2203.6 (73.5%)
7	0.06	2266.7 (75.6%)
7	0.08	2311 (77%)
7	0.1	2354.4 (78.5%)
8	0.04	2224.5 (74.2%)
8	0.06	2277.2 (75.9%)
8	0.08	2317.5 (77.3%)
8	0.1	2392.8 (79.8%)
9	0.04	2224.6 (74.2%)
9	0.06	2293.8 (76.5%)
9	0.08	2363.7 (78.8%)
9	0.1	2409.2 (80.3%)
10	0.04	2262.6 (75.4%)
10	0.06	2346.6 (78.2%)
10	0.08	2363.4 (78.8%)
10	0.1	2428.4 (80.3%)

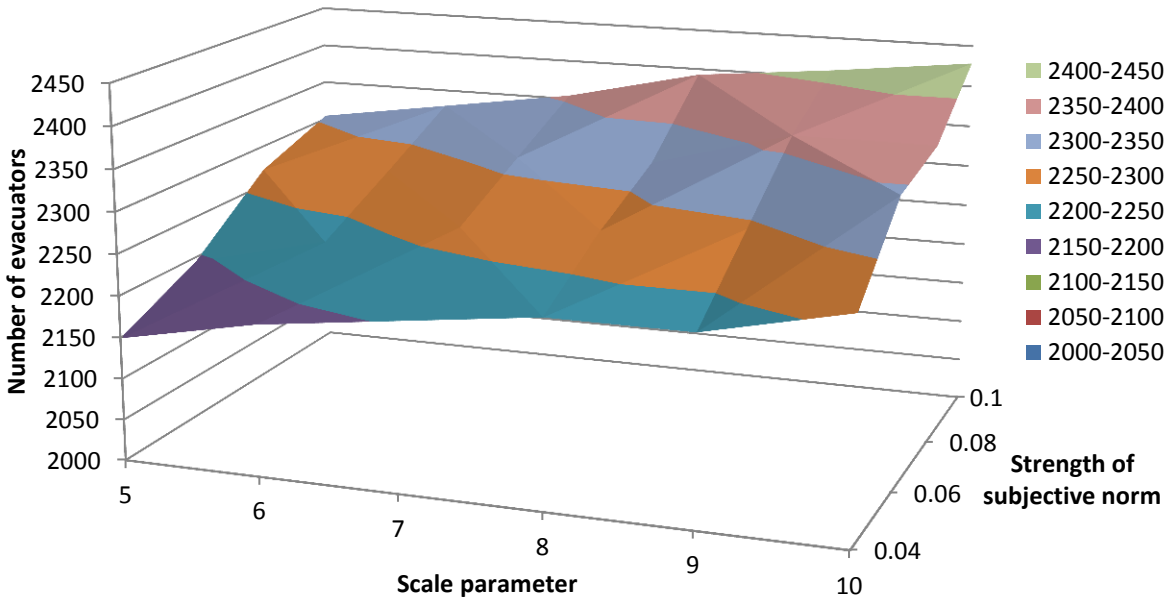

Figure 6.12: The effect of changes in size of scale parameter and strength of subjective norm in a scale free network

It must be noted that for a significant impact on evacuation rates, the size of the network would have to grow significantly. For the small world network, with a subjective norm strength of 0.04, when the size of the social network doubled from 5 people to 10 people the evacuation rate increased from 70.1% to 71.8%. The increase in a random network was slightly larger; from 70.9% to 73.7%. The scale free network, produced the largest increase from 71.6% to 75.4% when M increases from 5 to 10.

Having tested the effect of changing the size of the social network and the strength of the subjective norm together, it was then decided to further analyse the strength of the subjective norm as this was the parameter which had the bigger impact on evacuation. This time the strength of the subjective norm was tested from 0 to 1, with increments of 0.1. It was decided to conduct this experiment with the default network type and size, so all variations take place in a small world network of five people. Table 6.10 displays the results of these runs.

Table 6.10: Sensitivity test for the subjective norm for a small world network

Network size	Subjective norm	Evacuation result
5	0	2005.6 (66.9%)
5	0.01	2030.3 (67.7%)
5	0.02	2056.3 (68.5%)
5	0.03	2073.7 (69.1%)
5	0.04	2103.8 (70.1%)
5	0.05	2125.6 (70.9%)
5	0.06	2151 (71.7%)
5	0.07	2170 (72.3%)
5	0.08	2174.1 (72.5%)
5	0.09	2202.1 (73.4%)
5	0.1	2218.6 (74%)

Testing the strength of the subjective norm revealed some non-linear results. These are shown in fig 6.13, which depicts the difference in the number of evacuations per hour when the strength of the subjective norm is altered, relative to the default GEM. The default strength for the subjective norm is 0.05, and this is represented by a line which runs along the x-axis. In the first hours of the model's operation, there is a non-linear relationship between the strength of the subjective norm and the number of evacuators. Unsurprisingly, when the strength of the subjective norm is increased relative to the default strength, the number of evacuators increases. However, the proportion by which the subjective norm is increased does not have a clear relationship with the proportion by which evacuation is increased. For example, when the subjective norm is increased to 0.06 the difference from the default subjective norm peaks at 17.2%, and at 31.3% when the subjective norm is increased to 0.07. However, the corresponding figures for 0.08, 0.09 and 0.1 cluster together at 35.7%, 40.6% and 34% respectively. In fact, the clustering of these four lines is evident throughout the running of the model. The difference between the results for 0.06 and 0.07 is unexpected, and seems to be an example of emergent behaviour.

A different relationship describes the weakening subjective norm (figure 6.13). In general, when the strength of the subjective norm is decreased relative to the default, the number of evacuators decreases overall. However there is a good deal of noise apparent in the first hours of the model, with some of the lines crossing the x-axis,

representing more evacuation than the default model. The lines begin to cluster after about 09:00 on September 9th, and from then on almost mirror the results of the runs of the increased subjective norm. When the subjective norm is relatively weak, the peak in the differences from the default GEM occurs much later, ranging from 09:00 on September 8th for a subjective norm of 0.01, to 10:00 on September 11th for a subjective norm of 0.03.

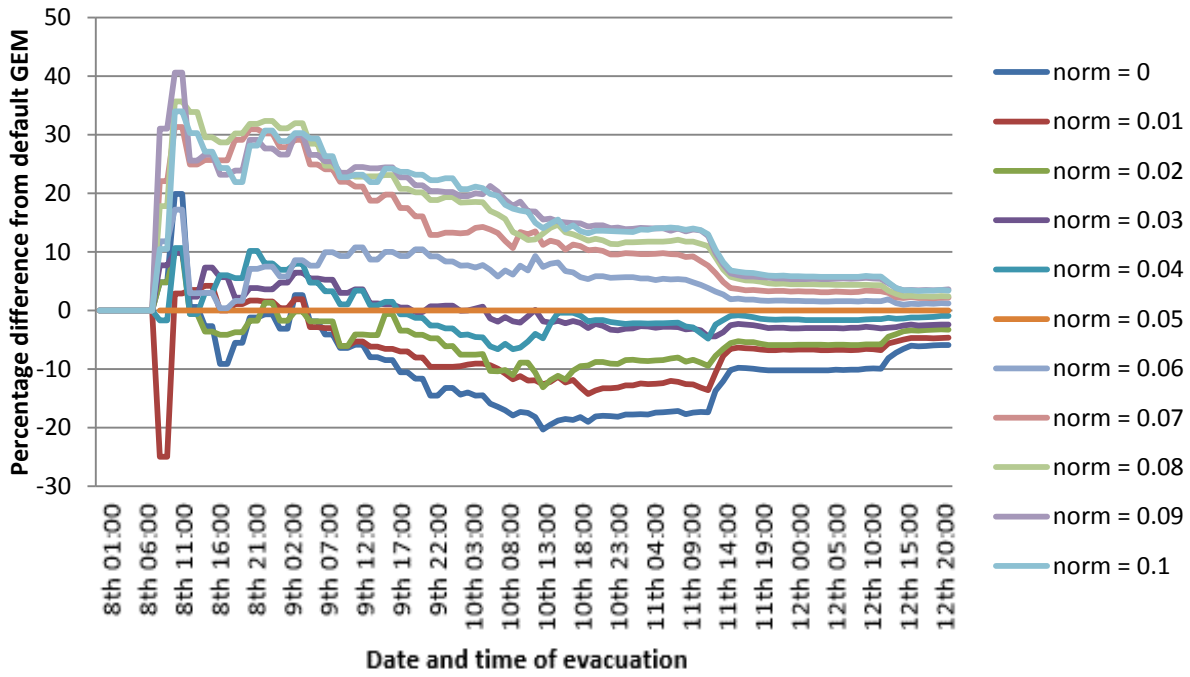

Figure 6.13: Evacuation timing for the different subjective norms relative to the default GEM

When the subjective norm is relatively strong, its peak impact on evacuation occurs at the very start of the model. This is not the case when the strength of the subjective norm is reduced below that of the default model (table 6.11). One would expect that a 20% increase in a parameter would increase evacuation by the same number that a 20% decrease in the same parameter would decrease it. Looking at the first 30 hours of the model this is not the case. Figure 6.13 shows that until approximately 06:00 on September 9th there are very few evacuators below the x-axis. After 09:00 on September 12th, all of the lines converge towards the default model, suggesting that the impact of the subjective norm is at its weakest at this point.

Table 6.11: Peak proportional difference from default GEM

Strength of subjective norm	Hour of peak difference	Difference from GEM
0	11:00 Sept 10th	-20.4%
0.01	9:00 Sept 9th	-25%
0.02	12:00 Sept 10th	-13.2%
0.03	11:00 Sept 11th	-4.4%
0.04	08:00 Sept 10th	-6.6%
0.05	N/A	0
0.06	11:00 Sept 9th	17.2%
0.07	11:00 Sept 9th	31.3%
0.08	11:00 Sept 9th	35.7%
0.09	11:00 Sept 9th	40.6%
0.1	11:00 Sept 9th	34%

6.11 Conclusion

The GEM accurately replicates evacuation behaviour for Galveston Island before the landfall of Hurricane Ike thus addressing research question 2.a. The model effectively integrated empirical data including that from the fieldwork reported in the previous chapter to build a model with proactive, reactive and communicative agents. This demonstrates that it is possible to understand island-level evacuation through subjective attitudes and subjective norms, questioning the importance of approaches which stress the hegemony of technical and socio-economic factors. The GEM was then also used to address research question 2.b. and investigate alterations in subjective evacuation attitudes, social networks and subjective norms and how this would produce changes to macro evacuation results. Altering the relative proportions of the agents holding each subjective evacuation attitude impacted on the island-level evacuation rate. Assuming the social networks on Galveston are presently organised as a small world, if the network type changes through policy or social change a higher rate of evacuation could result. Changing the size of the social network and the strength of the subjective norm also impacts on the evacuation result. Further examination of changes in the strength of the subjective norm suggests a non-linear relationship which indicates that the GEM produces emergent behaviour. By assuming that attitudes, subjective norms and social networks can change, using the GEM does

not assume constrained agency of the individual or household. How policy and social processes might result in such alterations is discussed in the following chapter.

Chapter 7: Discussion

1. Introduction

This chapter brings together the two empirical chapters and relates their findings to the literature review within the framework of the thesis. The literature review revealed that there are four main ways in which risk, and specifically hurricane risk can be understood; the technical, socio-economic, psychological and cultural paradigms. Adger et al. (2008) have written that the first two "exogenous" conceptualisations of risk which place the limits of adaptation outside of the individual's control have tended to dominate the climate change literature. It was argued in the literature review that this is also true for hazard and hurricane evacuation literature. This has led to a narrow framing of the problem of hurricane evacuation by policy makers. Under the technical understanding, non-evacuation is framed as being a problem of communicating and understanding hurricane risk. People are assumed to be "rational" decision makers, therefore non-evacuation is explained as a failure to receive the message, or else failing to decode the message. Under the socio-economic understanding of risk, non-evacuation is understood as the result of unequal access to resources and information. This means that some sectors of the community want to evacuate but cannot.

Therefore hurricane policy tends to be based on two simplistic assumptions. Firstly, under the technical paradigm, those who do not evacuate fail to do so as they are unaware of the risk. Secondly, under the socio-economic paradigm, those who do not evacuate are assumed not to have the means to leave. These assumptions seem to have led to two clear hurricane evacuation policies in Galveston. The One Call Reaches All – Emergency Notification System aims to communicate to the entire population of the island the necessity to evacuate, while the Citizens Response Team registers those in need of evacuation assistance and the City provides buses to enable evacuation for

those unable to leave independently. As these policies have failed to increase evacuation levels above 70-80%, it seems likely that there are other, neglected understandings of hurricane risk which can explain non-evacuation. Accordingly one focus of the thesis is to investigate the importance of the psychological and cultural paradigms for understanding hurricane risk.

In addition to this narrow understanding of risk, there is a parallel neglect of the impact of subjective norms and the social networks in which they are communicated. This is problematic as communication is becoming increasingly important due to advances in telecommunications and the increasing influence of social media in daily life (Crowe, 2011). It is assumed that the subjective norm which promotes evacuation when a community is under threat is spread through a social network. The framework of the thesis therefore used a risk-specific theory of decision making, protection motivation theory (PMT) (Rogers et al., 1983) incorporated into a more general understanding of decisions; the theory of reasoned action (TRA) (Fishbein and Ajzen, 1975). TRA, while recognising the importance of attitudes and subjective norms, does not specify how attitudes are formed. For this reason Sheeran et al.'s (2013) development of PMT is used to create a more rounded decision structure (see figure 2.6).

The initial research problem was the following:

> After being informed of a potentially devastating impact, why do 20-30% of people not evacuate from hurricanes?

After consideration of the relevant literature, the final research questions decided on were the following:

> 1. How do subjective evacuation attitudes affect hurricane evacuation decisions?
>
> 2. a. How do different subjective evacuation attitudes combine with subjective norms to create large scale patterns in hurricane evacuation?

2. b. How might changes in subjective evacuation attitudes, subjective norms and social networks alter large scale patterns in hurricane evacuation?

A Q study was chosen to investigate the subjective evacuation attitudes which are theorised as being formed by beliefs about evacuation, threat appraisals and coping appraisal, and so address the first research question. The Galveston Evacuation Model (GEM) was developed to simulate the impact of scaling up the subjective evacuation attitudes and subjective norms, theorised as comprised of normative beliefs and motivation to comply with those beliefs. In this way research question 2a was addressed. The GEM was also used to answer research question 2b, as it allows, through changing the parameters of the model, the investigation of how changes in subjective evacuation attitudes, subjective norms and social networks could affect island level evacuation.

7.2 Subjective evacuation attitudes and evacuation

Before a discussion of subjective evacuation attitudes, it is necessary to include a brief review of the findings of the fieldwork. Chapter 5 recounted how the Q study revealed four subjective evacuation attitudes which were salient in Galveston in the days leading up to the landfall of Hurricane Ike. In contrast to other studies explaining non-evacuation through technical (Fischhoff, 2006) and socio-economic factors (Eisenman et al., 2007), the Q study showed another way of understanding evacuation; through differentiated subjective evacuation attitudes (table 5.14) which emphasise the importance of psychological and cultural factors. The factor interpretation showed the Citizens tended to evacuate as they were influenced by official warnings, while the Pragmatists evacuated after making a subjective assessment of the risk in staying. This meant that on average the Pragmatists left later than the Citizens. Individualists tended not to evacuate; like Pragmatists they made a subjective assessment, but felt it was unnecessary to leave. On the other hand, the Believers tended to be influenced by their faith and most of them stayed and weathered the storm. Some of them believed that their religion would protect them, while another felt a need to stay and help others less able to help themselves in the aftermath of landfall.

The findings of the Q study can be used to assess the utility of the four paradigms of risk perception introduced in Chapter 2, with evidence to support each of them. The first paradigm to be considered is the technical approach. The number of Citizens who evacuated supports the contention that a large section of the community will evacuate if they receive an order from someone with authority (Gladwin et al., 2001). As authorities seem to be trusted to make public safety decisions, this study provides evidence to support the work of Drabek (1986) who claims that if authorities are deemed to have correctly issued warnings in the past their judgement will be trusted. The behaviour of the Pragmatists seems to support the work of Perry and Lindell (1991), who believe that when residents are presented with appropriate information about a hurricane's course, intensity and size, they are likely to evacuate. Indeed the Pragmatists kept themselves informed and evacuated once they deemed staying to be sufficiently risky. Another interpretation of the evacuation of the Pragmatists is they take no notice of the official risk areas; what is relevant to them is self-reported risk areas. This supports the work of Zhang et al. (2004) and Arlikatti et al. (2006) who stress the importance of self-reported risk areas in the evacuation decision. In this way the existence of Pragmatists is an example the of differentiation of subjective evacuation attitudes. It could be argued that both the Citizens and the Pragmatists support the idea of rational man as both evacuate in order to avoid negative consequences. It just happens that the triggers for these evacuations are different; for the Citizens it is the mandatory evacuation order, while for the Pragmatists it is the onset of flooding caused by the forerunner surge.

A clearer example of the differentiation of subjective risk attitudes comes through an examination of the Individualists. The Individualist discourse sees subjective perceptions of risk as favourable to the supposedly objective risk perceptions of experts and city officials. Essentially the Individualists tended not to evacuate as they felt safe, supporting the findings of Riad et al. (1999). Some of the Individualists also believed they were sufficiently prepared to live through the hurricane and its aftermath unscathed. This goes against the technical paradigm and the idea of rational

man as different people in similar situations have differentiated subjective evacuation attitudes which contribute to polar opposite evacuation decisions.

The Q study also provides some evidence supporting the socio-economic paradigm of hurricane evacuation. One of the non-evacuating Citizens said that he had initially intended to leave, but as he did not have a car was dependent on his brother for transport. Through a misunderstanding, the lift did not materialise and at this point it was too late to take an evacuation bus. Therefore, in this case, a lack of personal transport acted as a barrier to evacuation as suggested by Wolshon et al. (2005). For one of the non-evacuating Believers, it is likely that his socio-economic status contributed to him staying and weathering the storm. He claimed that he could have left had he wanted to, but the interview made at the time of the Q study suggested that he was actually limited by his work commitments as a security guard. Therefore it seems that his non-evacuation can be at least partially explained as not being allowed to leave, supporting Lindell et al.'s argument that socio-economic class can act as a barrier to evacuation (2005).

Another argument made by advocates for a socio-economic explanation for non-evacuation is that a knowledge gap exists between demographic groups, with Caucasians and more educated groups better informed about hurricane risk than minorities and people with less education (Lachlan et al., 2007). The fact that all of the Pragmatists were Caucasian and well educated could indicate that a knowledge gap exists. Conversely two of the Individualists who did not evacuate were Caucasian with post graduate qualifications and above average salaries. It has further been claimed that single males with low levels of education are more likely to stay and weather the storm (Bateman and Edwards, 2002). In the case of the Individualists, this was not the case. Although four of the five Individualists were single, all were aged over fifty, two were female and two had postgraduate qualifications. All of the participants loading as Believers were ethnic minorities, but from the Q sorts and interviews it did not seem that their non-evacuation can be explained by the knowledge gap hypothesis, as they seemed quite well informed as a group. At first glance it would appear that ethnicity could be a limitation to evacuation for this group. However the Q study sheds new

light on this understanding, as for the Believers who stayed, it was generally an agential decision not to evacuate. Therefore this research supports the claim that minorities might indeed have different understandings of risk (Perry, 1987; Dake, 1992) and/or different coping strategies (Peacock et al., 1997) and these might result in non-evacuation. Their decisions might be dependent on their religious views, but this is very different to claiming that it is ethnicity which acts a barrier to evacuation (Price, 2008).

Part of the psychological paradigm stresses the importance of heuristics; mental short-cuts made below the level of full consciousness (Kahneman, 2012). It was apparent that Hurricane Katrina had an impact on some of the Citizens. After seeing the death and destruction which that hurricane had brought three years previously, some Citizens seem to have decided it was a case of “better safe than sorry”. This could be an example of the availability heuristic (Tversky and Kahneman, 1973), with Katrina the first example which comes to mind when they considered the potential impact of a hurricane. On the other hand, it also seems that negative experiences of evacuation during Hurricane Rita may have swayed the opinions of Individualists who did not evacuate. This could be a different result which derives from the availability heuristic. As Rita was the last evacuation and was considered inconvenient and perhaps even dangerous, this is the evacuation by which the next evacuation was judged. A related interpretation would argue that this provides an example of the “crying wolf” effect found by Dow and Cutter, whereby residents are lulled into a false sense of security (1998).

Some of the Citizens said that they evacuated out of habit, and some of the Individualists said they did not evacuate for the same reason. This supports one of the findings of another study on Hurricane Ike (Morss and Hayden, 2010), which also found evacuation is conditioned by habit. It is also possible that the Individualists might have displayed an optimistic bias (Weinstein, 1980). They could have thought that either the risk was not significant enough to warrant evacuation, or that their personal circumstances meant that it was not necessary to leave. For example, they might have believed their housing or their character to be especially tough or resilient. If this was

the case, they might have felt it was prudent for others to evacuate, but not necessary for themselves. This is also a possible explanation for the Believers who stayed in order to help those non-evacuators unable to help themselves. Evidence of the use of heuristics further supports the contention that people are not rational decision makers. If decisions are being made semi-automatically, then they cannot be the result of a conscious cost-benefit analysis. This is most clearly displayed through the availability heuristic (Tversky and Kahneman, 1973) and evacuation habits resulting in opposite evacuation decisions.

It seems possible to argue that some of the Believers have a low coping appraisal, or display trait anxiety (Weinstein et al., 2002). This means that they do not believe that they can protect themselves, so they transfer their responsibility onto others. In this case it means that they trust in higher beings for protection. It could be argued that this is a socio-economic barrier to evacuation, but if residents know they can get evacuation assistance then it could be argued that this apparent transfer of agency reflects a psychological barrier.

From the Q sorts and interviews with the Individualists, it is clear that the judgement of officials is not always taken at face value. This concurs with research on Hurricane Katrina which found some New Orleans residents did not leave due to a historical distrust of public figures (Cordasco et al., 2007). In the case of Katrina it is argued that this distrust has a political economy centred on ethnicity (Price, 2008). It is unlikely the same can be true for the Individualists as those who did not evacuate were all Caucasian. It was apparent there was a lack of trust in the media and government who are thought to exaggerate the threat of hurricanes, but the Individualists did not believe that the authorities had a hidden agenda. This distrust of officials could be part of a culture of lack of faith in government, which is not uncommon in the USA and Texas.

The non-evacuation of the Believers was in the main motivated by the belief that a higher power would protect them, or that they would be required to help out those

less able to help themselves in the aftermath of landfall. The fact that some of the Believers stayed as they thought they would be protected supports Haque's (1995) findings on non-evacuation in Bangladesh having a religious explanation. As mentioned above, all of the Believers were ethnic minorities, with three African Americans and two Hispanics. As the Believers were likely to stay and weather the storm, the study appears to corroborate one of the findings of Elliot and Pais (2006), namely that African Americans often rely on their religious faith and this can have implications for evacuation. The existence of the Believers also lends support to the research of Stephens et al. (2009), who claim some people do not evacuate in order to provide assistance for members of the community who also stay behind. This appears to show that an altruistic community exists on Galveston (Flynn at el, 1999). It is also possible that those Believers who do not evacuate are actually looking for an opportunity to display courage and seek recognition as Giddens (1991) has suggested. Likewise, non-evacuating Individualists might feel the need to distinguish themselves as superior to the rest of society (Macgill, 1989; Frank et al., 2011) as they can display their resilience.

The Q study therefore provides evidence supporting each of the four paradigms of hurricane risk. It seems that some Galvestonians might think in an economically rational manner as they took protective measures and evacuated either when they were recommended to do so, or perceived the risk to be imminent when the water started to inundate the island. This thesis argues that those residents who did not evacuate had their own reasons too. For some, the hurricane was not sufficiently risky to warrant an inconvenient evacuation, while for others their faith meant that they felt protected on the island, or felt they needed to stay to be able to help. Each reason was rational according to their subjective evacuation attitude, therefore it is essential to move beyond positions which only recognise the technical and socio-economic paradigms, and embrace a wider understanding of hurricane risk.

7.3 The disconnect between evacuation policy and the subjective reality

Evacuation policy largely conforms to the technical paradigm of risk as it is based upon the assumption that people are rational decision makers. The technical approach

suggests that residents are likely to evacuate if they are informed of the likely path and intensity of the hurricane (Perry and Lindell, 1991), and the likelihood of evacuation increases if information is communicated clearly (Perry et al., 1981), consistently (Drabek, 1986) and frequently (Boggs and Drabek, 1968). The Q study suggests that this is a simplistic and perhaps damaging assumption as differentiated subjective evacuation attitudes lead to differentiated evacuation results. Risk communication will persuade some residents to evacuate, but not others. Although on the whole Citizens tended to respond to official declarations, Gladwin et al. (2001) are correct when they state that only *some* members of society are directly influenced by the authorities' judgement on when it is necessary to evacuate. Pragmatists tended to make their own decisions based on their interpretation of risk communication and environmental cues. Individualists, as the name implies, were not influenced by official warnings and made their own decisions according to their subjective evacuation attitude. This meant they are unlikely to be influenced by further risk communication. Believers are also unlikely to be influenced by risk communication, as whether they believe that they are at risk is less relevant; their faith means they might even be more likely to stay if they deem the risk to be higher.

The socio-economic paradigm of risk is based on the understanding that structural barriers prevent some residents from evacuating. Evacuation policy makers suppose that those unable to leave on their own will leave if they are given material assistance. While some residents were indeed helped and evacuated, the Q study revealed that for the majority of those who did not evacuate, material ability to evacuate was not the most important factor. One of the Citizens interviewed in the Q study did benefit from evacuation assistance, though from a local church as opposed to the City Government. The Pragmatist perspective constructs the situation as one in which they were in control of the situation and were able to evacuate if and when they deemed the threat to be sufficiently serious. The Individualists who weathered the storm did not do so as they were unable to leave, rather it was a deliberate agential decision. The Believers who stayed on the island preferred to stay and weather the storm and were not constrained by material factors, although it did appear that one of them could not have left even if he had wanted due to work commitments.

Homo economicus implies that people think and act in a narrowly defined version of their own best interests. In the case of hurricane evacuation, an economically rational person would evacuate because to stay on the island brings increased risk of death, injury and discomfort. However, the Q study highlighted four distinct subjective evacuation attitudes, suggesting heterogeneity of rationality. Whilst for some of the participants in the Q study, evacuation was the rational choice, for others it was not. On the whole it was rational for the Citizens and the Pragmatists to evacuate, but as the Q analysis revealed, even these two evacuating groups have distinct rationalities. The Citizens were likely to be influenced by the mandatory evacuation order, while the Pragmatists were motivated by the rising water caused by the forerunner surge. The subjective evacuation attitudes of the other two groups are more widely differentiated. It could be argued that for the Individualists, staying is a rational choice; they made a calculation that they were better off staying than evacuating as they believed that the hurricane was not sufficiently dangerous to them to outweigh the inconveniences of evacuation. Of course a traditional economist may suggest that this is irrational as they are overweighting comfort relative to safety. Non-evacuation is viewed as detrimental from a public health perspective, but for most of the Individualists the decision to stay was not viewed as a mistake; to them staying was a correct, and rational decision.

A similar analysis can be made for the Believers, suggesting that their decision to stay was also rational. For the Believers, their strongly held spiritual or moral worldviews impacted on their subjective evacuation attitudes and decision to stay. It is possible to subdivide the non-evacuating Believers into those whose decision to stay was influenced by a belief that a higher power would save them or the desire to stay and help those unable to help themselves. Again, economic man as normally defined would not make such a choice. Since the enlightenment the view of the scientific community is that higher beings do not exist, therefore any worldview that accepts, and depends on celestial assistance is classed as irrational. However, if a person defines themselves through their religion or spirituality it is natural that their actions will be influenced by their worldview. If this is a definition of irrationality then most of

the world's population is irrational. Likewise helping other members of a society is a widespread occurrence, so deeming it irrational is problematic.

It is the contention of the author that rationality in the singular is an unhelpful positivist construct. The results of the Q study support the critiques of homo economicus, which at best can be applied to some people some of the time. To base a policy on the assumption that everyone thinks economically rationally all of the time is a mistake. Clearly differences exist across and within societies and we should speak of rationalities in the plural. Once this has been accepted, it becomes possible to first better understand these rationalities, and hence consider policies which will work with these rationalities to encourage evacuation policy. This does not necessarily mean that the goal of maximising evacuation rates will be met; it might also mean designing measures to cater for those who are likely to make a subjective rational decision to stay.

7.4 The utility of a Q study for investigating subjectivity

This thesis has shown a Q study can be a reflexive research tool (Ockwell, 2008), although care has to be taken to minimise researcher bias at every stage of the process. As the majority of the statements used for the sorting process were direct quotations from residents of Galveston made in the lead up to the landfall of Hurricane Ike, the participants were able to express their subjectivity effectively, so it was the ideal method for revealing the subjective evacuation attitudes of the respondents. This means that the Q study is a step in the right direction towards recognising the agency of the residents of Galveston. One characteristic of a Q study is that it can normally only reveal a limited number of attitudes. Although in this study 36 of the 40 participants loaded on one of the four factors, four of the participants did not load purely on one of the factors and so were discounted in the analysis. By its very nature, factor analysis simplifies data and some participants' viewpoints are not given as much attention as others. Nevertheless as the intention of the Q study was to highlight the most widely held subjective hurricane attitudes, this is not necessarily a weakness of the method. An aspect of a Q study which is perhaps undervalued is the enthusiasm

with which participants take to it. With one exception, all of the 40 participants seemed to be engaged with the activity and as a researcher it certainly felt a less intrusive research tool compared to conventional interviews. This meant that the participants relaxed and opened up whilst performing the sort. The vast majority of participants enjoyed the process and the mechanics of the sort posed few problems. The fact that so many participants enjoyed the interview led to recommendations that others should also participate, facilitating snowball sampling.

7.5 The interaction of subjective evacuation attitudes and subjective norms

The Q study unveiled four distinct subjective evacuation attitudes which seem to have a strong influence on island-level evacuation. In order to investigate the impact of these attitudes on island level evacuation it was necessary to use another method which enabled scaling up to a larger sized population. According to the TRA, decisions are not only made due to attitudes, but are also influenced by subjective norms (Fishbein and Ajzen, 1975). Interviews conducted on the Q sorters revealed that the majority discussed evacuation with friends, family and colleagues. This supports the idea of decisions made through the process of social milling (Mileti and Peek, 2002) and that risk is best understood as a social phenomenon (Smith and Kain, 2010). To investigate subjective norms, it was also necessary to investigate social networks, which act as their conduit (Wynne, 1989). As people are typically unaware of the influence of others on their decisions (Christensen and Ruch, 1980), traditional methods are not well suited to researching this area. ABMs are methods which can enable the simulation of large populations and are designed to investigate social interaction (Macal and North 2010). Therefore it was decided to build an ABM to model the impact of the subjective evacuation attitudes and subjective norms.

The Galveston Evacuation Model (GEM) demonstrates the possibility of using an ABM to accurately replicate the real life evacuation from Hurricane Ike for Galveston Island. In order to discuss its findings, it is useful to briefly review its design. The model was parameterised with a combination of empirical data from two distinct but mutually

supporting sources. The calibration data (Van Zandt 2010) provided accurate information on when the evacuation took place, while the Q study provided equally rigorous data on the relationship between subjective evacuation attitudes and evacuation decisions. Owing to the problems of acquiring information on subjective norms and social networks, it was also necessary to use theory to parameterise the model, and to sensitivity test the parameters derived from theories. The small world network was used as it reflects the idea that people no longer only communicate with people who are in their immediate vicinity and communication is less spatially constrained (Crowe, 2011). The GEM was built in stages, firstly the calibration data was used to parameterise the hourly evacuation rate and the diurnal surge. Then the Q study data was used to parameterise the impact of the mandatory evacuation order and the onset of flooding caused by the forerunner surge.

It was only through including the subjective norm that the evacuation curve of the GEM reflected the evacuation curve of the calibration data. As a result this study supports findings which claim evacuation decisions are influenced by how individuals think their decision will be interpreted by their significant others (McIvor and Paton, 2007), by explaining some evacuations through the influence of subjective norms. This is evidence that social milling does occur (Mileti and Peek, 2002), and suggests that at least some of the community's evacuation decision making should be viewed as collectivistic, as opposed to individualistic (Quarantelli, 1985). The findings of the GEM support a review of research which found that 16-30% of evacuators from hurricanes in the USA were influenced by their social network (Christensen and Ruch, 1980). However, it should be noted that the GEM investigates direct decisive influence – whether a person is persuaded to evacuate through subjective norms communicated through social networks. As such, in the GEM the proportion of agents evacuating due to the direct impact of the subjective norm is lower than these figures, but it can be assumed that some agents are influenced, without being persuaded. In general the results from the GEM support the contention that attitudes are more predictive of behaviour than subjective norms (Trafimow and Fishbein, 1994).

The GEM recognises agency in the householders of Galveston as it enables the agents to be proactive, reactive and communicative (Kniveton et al., 2011). The agents are proactive as they have an underlying likelihood of evacuating and increased probability of evacuating; this is parameterised with empirical data. The agents are reactive as they are more likely to evacuate following certain events. The reactivity is a characteristic of the subjective evacuation attitudes as revealed by the Q study. This means the agents are not assumed to be homogeneous robots, but heterogeneous persons. The agents are communicative as the subjective norm encouraging evacuation is transmitted through the social network. This is parameterised through theory and sensitivity testing and leads to increased evacuation.

As there are a number of ways in which the model could have been parameterised in order to reflect the calibration data, it is impossible to claim that the GEM is a definitive explanation of how the evacuation occurred. Nonetheless, as it is based on empirical and theoretical findings, and the number and timing of evacuations resembles the calibration data, the GEM offers a plausible explanation of the evacuation for Ike. This suggests that one way of explaining island-level evacuation is through the study of subjective evacuation attitudes and subjective norms operating through social networks. As a result the thesis also supports the use of the TRA for explaining hurricane evacuation.

7.6 The impact of changes in changes in subjective evacuation attitudes, subjective norms and social networks and policy recommendations

Once this convergence was achieved, further sensitivity tests were performed on the default GEM. The GEM was first altered to test the impact of changes in subjective evacuation attitudes, before the size and type of the social network and the strength of the subjective norm were altered. The reasoning behind these alterations was to demonstrate the range of evacuation results which could occur in the future.

The GEM was first altered to test the impact of a potential change in subjective evacuation attitudes on the island-level evacuation result. It shows that through minor

changes in attitudes, very different evacuation results could occur. When the number of agents holding the attitudes of Individualists or Believers declined relative to the number with the attitudes of Citizens and Pragmatists, the total number of evacuators rose. This means that in addition to the agency which the default model assumes on the behalf of the agent, the variation grants further agency to the agents. The population variation assumes that it is possible for subjective evacuation attitudes to change and this could result in very different island-level evacuation results. It is desirable to consider how this change might take place. It is possible that simply through their non-evacuation experiences some Individualists and Believers may evacuate the next time a hurricane threatens Galveston. In the interviews accompanying the Q sorts, one of the Individualists and one of the Believers explained they would be likely to evacuate next time.

Although the Citizens and Pragmatists were likely to evacuate, their motivations for leaving were rather different. For those evacuating on the 11th of September, the Citizens seemed to be motivated by the fact that the evacuation had been mandated, while for the Pragmatists, a mandatory evacuation might be best understood as a proxy for increased risk as well as a warning that staying on the island would mean living with a lack of services. These considerations would make evacuation a pragmatic choice. This means that even if in the model Citizens and Pragmatists are motivated to leave by the same two events, the exact reasons that these events trigger evacuation might be rather different.

As figure 7.1 shows, the four subjective attitudes can be divided in a similar vein to the conceptualisations adopted within Cultural Theory (Douglas and Wildavsky, 1982). Douglas and Wildavsky situated people according to how individual/community minded they are on one axis and how much agency a person has on the other axis. From the results of the Q study it is also possible to divide the participants of the Q study along an axis of agency, with the other axis representing risk perception. It can be seen that the Pragmatists have a high perception of risk and make autonomous decisions while the Citizens have high perception of risk but make dependent decisions. The Individualists have a lower perception of risk and make autonomous decisions and

the Believers also have lower perception of risk but make more dependent decisions. Individualists and Pragmatists can be seen as somewhat alike, as on the whole both groups make autonomous decisions, the difference being the level of risk perception. In the case of the Believers, decisions partly depend on their religious or ethical beliefs. They might not evacuate from the incoming hurricane as they believe that God will protect them or feel that they need to be in the city after the hurricane to act as a Good Samaritan. In the case of the Citizens, their decision to evacuate is somewhat dependent on experts and Government as it is prompted by weather warnings and the mandatory evacuation order.

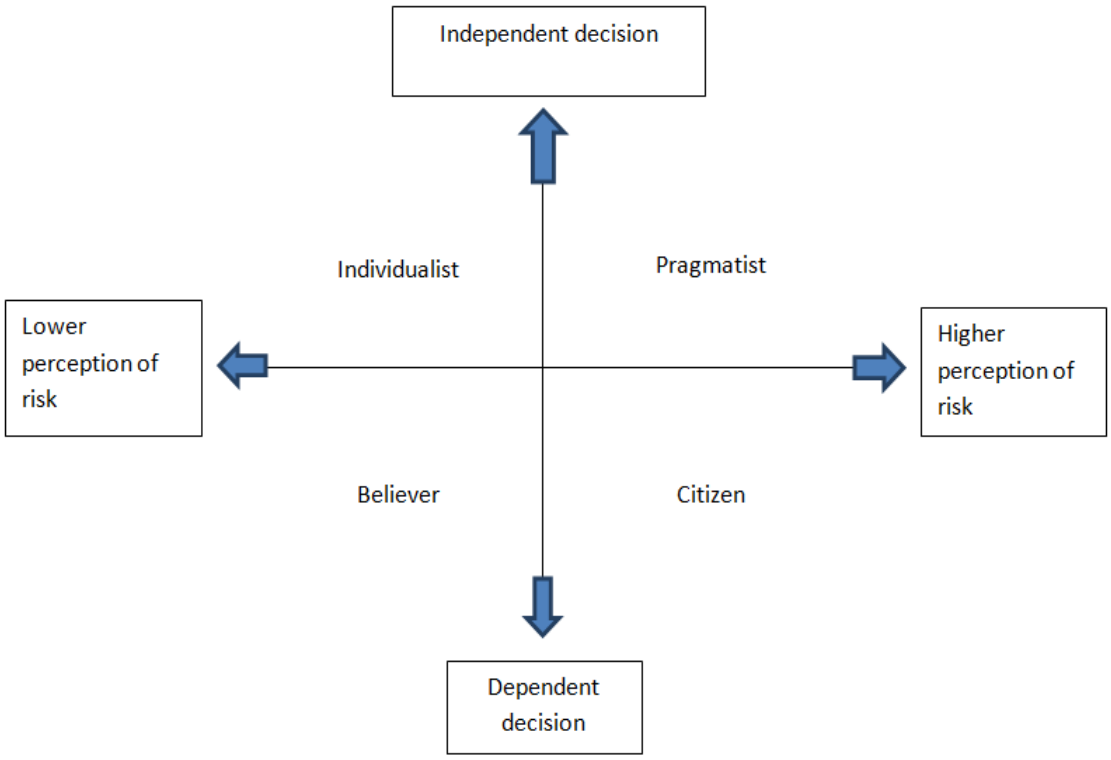

Figure 7.1 : The risk-autonomy grid. Adapted from Douglas and Wildavsky (1982).

In this way, it can be seen that in some respects, the Citizens think like the Believers, while the Pragmatists think like Individualists. Going further, there are demographic similarities between the participants who loaded as Citizens and Believers, and those who loaded as Pragmatists and Individualists. The majority of particpants who loaded

as Citizens or Believers were African American or Hispanic, while the most of the particpants loading as Pragmatists or Individualists were Caucasian and well educated.

The effect that the potential alteration in attitudes could have on island-level evacuation levels was tested by the GEM and recounted in the previous chapter. The population variation showed that if the proportion of Individualists and Believers falls as the proportion of Citizens and Pragmatists rises, there will be a significant rise in the number of evacuators. In the default version of the GEM, Individualists represent 25%, and Believers 15% of the population, and the evacuation rate was 70.9%. When the proportions of Individualists and Believers falls to 20% and 10%, the evacuation rate increased to 76.2%. When the proportion is 15% and 5%, the evacuation rate is 81.6%, and when there are 10% Individualists and zero Believers the evacuation rates reaches 87.6%.

Texas policy is committed to 100% evacuation and the state wishes to avoid costly rescues (FEMA, 2010); therefore it is useful to consider how evacuation rates could be increased. This study suggests that if policy makers are determined to maximise evacuation rates, one way of tackling it would be to implement policies designed to appeal directly to the subjective evacuation attitudes revealed in the Q study. In their research on earthquakes, McIvor and Paton (2007) claim that people tend to adopt positions which support and reinforce their worldviews. For this reason the passive presentation of risk communication will not have any impact on some people as they are likely to interpret any information through their own subjective evacuation attitudes. This means that for risk communication strategies to succeed they need to recognise and adapt to these constructs. The first step in encouraging attitudinal change should be through recognising and validating the position of the non-evacuators (Morrow, 2009). Through engagament with the community and its shared characteristics it might be possible to gain a better understanding of why, within ostensibly similar communities such as the Citizens and Believers, and the Pragmatists and Individualists, there is a variety of evacuation behaviour.

Subsequently, over time it might also be possible, through constant engagement with the population of affected areas, to promote attitudes which favour evacuation (Hardin and Higgins, 1996). Appealing to the civic minded Citizens is relatively simple as this is what evacuation policy successfully does at the moment; it uses figures in authority to warn residents that they are at risk. This probably works because Citizens feel they are part of a community; they identify with it and feel a sense of duty. They have confidence in the source of hurricane information which is not considered as emanating from untrustworthy sources detached from the community. They tend to view the state as valid and interpret its communication as objective and internal to the community. Likewise, further appeal to the safety conscious Pragmatists is unnecessary, as they tend to evacuate when they consider themselves at risk, albeit it on average later than Citizens.

Individualists might mistrust the source of information, perhaps derived from a view that the state does not have the right to control people. Hurricane communication is seen as subjective and originating from the realm of the "other" and therefore external to them. It could be argued that for Individualists, the low perceived risk of the hurricane was partially related to a lack of trust in the authorities. The issue of trust could be tackled through an increased involvement of residents in emergency planning. This would bestow ownership of and identification with protection measures, increasing a sense of agency and wellbeing, while reducing the sense of "otherness" of such procedures. Some of the Believers are motivated by higher authorities. One obvious way of attempting to engage with the Believers would be to spread the message of evacuation through churches and other religious institutions, although this could only work for those Believers who are members of a congregation. For those Believers who are motivated by altruistic goals, one way of increasing evacuation compliance would be to reduce the need for altruism. If fewer people and in particular fewer needy people are expected to weather the storm, then fewer altruistic Believers might stay to help. It might also be possible to engage with such people's altruistic tendencies by encouraging them to communicate with other members of society to foster an understanding of different subjective evacuation attitudes. This could serve to build trust and potentially work towards creating new evacuation policies.

If these processes were successful, it could subsequently be possible to frame information and policies in such a way as to emphasise a plurality of meaning (Kahan et al., 2007). This would simultaneously recognise the validity of distinct subjective evacuation attitudes and build trust with different groups. Information and policies would take the form of appealing to the Citizens' respect for authority, the Pragmatists' common sense, the Individualists' sense of independence and the Believers' religious or moral beliefs. It is seems that the Believer who did not evacuate in order to help others experienced a redefinition of self from "me" to "us" (Drury et al., 2009) in the traumatic days leading up to landfall of Hurricane Ike. This suggests that some aspects of attitudes are malleable as Petty et al. (1997) claim. Therefore it is possible that a similar change of attitudes could occur over time on a macro level.

If a resident's subjective evacuation attitude dictates that staying is more beneficial than evacuating, they will most probably stay even if an objective risk assessment considers this irrational. However, if the costs appraisal reduces, then it is possible that attitudes and evacuation decisions will change. For example, in recent years the cost of public evacuation has been reduced for pet owners through schemes which allow them to evacuate with their animals (Brackenridge et al., 2012). The costs of evacuation could be further reduced with a more efficient re-entry process, as from the Q study it seems residents might be put off by the red-tape which has prevented them from returning to clear up their property in the past. Increasing the costs of staying would be extremely challenging. Any legal requirement for evacuation would be controversial, expensive and impossible to enforce. Closing centres of last resort and making residents liable for rescue costs are other political impossibilities as they might lead to extra deaths and injury. Any reduction of skeleton services post-landfall would also be seen as unnecessarily harsh on those who weather the storm. This suggests it would be sensible for policy makers to continue to promote policies with the aim of reducing the cost appraisal of evacuation as opposed to the increasing the costs of staying.

On the other hand it might be more expedient for policy makers to accept that a certain percentage of the population is likely to stay and weather the storm.

Individualists and Believers will not leave if according to their own subjective hurricane attitudes, it makes more sense to stay despite policy actions. Regardless of the dangers which a hurricane brings and the public health warnings which advise not staying in the aftermath of a hurricane, it could be argued that non-evacuation was the correct choice for some residents. That was certainly the opinion of some of the Individualists, who were scornful of the certain death warning and claimed in similar circumstances they would choose to stay again. The fact is that for many of these people, staying was and continues to be, a rational choice as long as their health is not impacted. Therefore there is a need for reactive policies to better cope with the population which will inevitably stay behind in the event of a hurricane, in tandem with proactive policies to increase the rate of evacuation. An acceptance that there is no "one size fits all" hurricane evacuation policy would be useful, as would the recognition that for some people in some hurricanes, staying might actually be the best solution.

The second variation of the GEM involved performing sensitivity tests on the size of the social network and the strength of the subjective norm. As expected, as the number of contacts in a social network increases, the more likely it is that an agent receives a recommendation to evacuate, although for the default strength of the subjective norm, the increase was minimal. This supports findings that the more contacts a person has, the more likely they are to receive a recommendation to evacuate (Perry, 1979), and those with smaller social networks are less likely to evacuate (Boggs and Drabek, 1968). Widener et al. (2013) also found that an increase in network size led to increased evacuation levels. It must be noted that for a significant impact on evacuation rates, the size of the network would have to grow substantially.

An increase in network size might evolve organically due to the influence of social media and communication technology. As the use of social media becomes more widespread, it can be assumed that residents might expand their range of contacts with whom they communicate, exchange ideas and influence. It is also possible that policy could promote the expansion of social networks as a method of ensuring that risk is communicated effectively and people are convinced to evacuate (Crowe, 2011).

It is important to note that an increased network size does not necessarily mean that evacuation will be more likely. The GEM assumes that the subjective norm encourages evacuation. In fact it is almost certain that there is another subjective norm which encourages people to remain on the island and weather the storm. Therefore an expanded social network might actually discourage evacuation.

The experiment which changed the strength of the subjective norm showed how the evacuation result could change if the effect of peer group pressure intensified. According to Fishbein and Azjen (1975), this could occur if a person thinks most people think the person should adhere to the subjective norm, and whether the person feels the need to comply with these expectations. The strength of the subjective norm encouraging evacuation might increase if a sense of group identity increases (Johnston and White, 2003) or through increased fears of social disapproval (Latimer and Martin Ginis, 2005). This could be encouraged through policy which seeks to engage disparate communities. Equally these changes might evolve through natural processes. It can be assumed that a stronger subjective norm might occur if members of the network perceive the next hurricane as especially dangerous, for example if the hurricane is predicted to make impact as a major hurricane (category 3-5 on the Saffir-Simpson scale). Therefore it is also possible that the strength of the subjective norm could alter under climate change, if the social network perceives hurricane risk to have increased.

When the strength of the subjective norm increases, the evacuation result also increases. Further analysis of the change in subjective norms revealed some non-linear relationships concerning the timing of evacuation. For a network size of five people, when the strength of the subjective norm is increased, its peak impact on evacuation occurred at the start of the model. This is potentially important as it suggests that changes in subjective norms could encourage both higher rates of evacuation and earlier evacuation. Earlier evacuation is desirable for policy makers as some people may get trapped if they leave it to the last minute and there will be less stress on the evacuation routes which tend to get extremely crowded in the peak times of evacuation (Stein et al., 2010).

When the strength of the subjective norm is decreased, the peak impact on evacuation occurs later on. This is interesting because the deviation from the default evacuation result is both earlier and larger when the strength of the subjective norm is increased. It is possible to explain a proportionally large deviation from the default GEM early on in the model as because the number of evacuators is low, a small difference in quantity can be a large difference proportionately, but this does not explain why there is such a lack of symmetry through the x-axis. In a linear model, one would expect that a 20% increase in a parameter would increase evacuation by approximately the same amount that a 20% decrease in the same parameter would decrease it. There is a linear relationship in the final evacuation result after the model has run its course, and eventually the different runs converge. This is when the overtopping occurs and the last diurnal surge is having an influence, but as most would be evacuators have already left at this point, there are neither enough messages being sent, nor enough agents receiving messages for the strength of the subjective norm to cause significant differences in evacuation.

When examining the differences in evacuation relative to the default strength of the subjective norm, it was found that for a network size of five, an increase in the subjective norm from 0.05 to 0.06 and 0.07 brought a seemingly linear increase in the peak difference from the default of 17.2% and 31.3%. Once the subjective norm was increased to 0.08, 0.09 and 0.1 the difference in evacuation from the default GEM did not increase linearly. Instead the peak differences from the default GEM cluster between 31.3% and 40.6% (table 6.12). These unexpected results could be examples of emergence, as there is no obvious explanation for why the changes were not more linear. Each variation of the GEM was done ten times, which minimises the chance that results are the results of the random numbers in the system, and indicates that the non-linearity is systemic, or emergent.

Variations of the GEM also suggest that the type of network has an effect on the final evacuation result. The small world network results in less evacuation than a random network as the influence of the subjective norm spreads mainly within neighbourhoods. There is some longer distance communication, but much less than for

a random network which results in more evacuation than the small world network, as the influence of the subjective norm spreads more quickly across the island. These findings concur with Widener et al. (2013) who also found that random networks lead to more evacuation than small world networks. The scale free network results in the largest number of evacuators. This could be explained by reference to Taylor's (2009) concept of opinion leaders; members of the community with especially high levels of influence on their social networks. This is modelled by connecting some hub agents to more people than the average member of the network.

The three network types are all theoretically possible. It is likely that a type of small world network exists now in Galveston, as while residents are more likely to communicate with their neighbours, it is implausible that communication is only with people in close proximity. The random network describes connections which are not constrained by distance; this is possible with the development and diffusion of telecommunications and social media. The networks on Galveston might also be explained as scale free as residents do not all have the same number of contacts. This network type might become more likely in the future if relevant persons are targeted by policy to expand their network and become social hubs with more contacts than the rest of the community. Scale free networks are extremely sensitive to the addition or removal or particular nodes, therefore targeted intervention focused on those residents with more contacts could be a very effective method of encouraging evacuation. On Galveston, there are a range of people who might be classified as opinion leaders, such as religious leaders, government employees and other people who are particularly active in the community such as ethnic minority leaders. These people are likely to have larger social circles and thus are both more likely to be influenced and more likely to influence others concerning evacuation decisions.

7.7 The utility of an ABM for understanding community level hurricane evacuation

The first use of an ABM to investigate hurricane evacuation decision making was published towards the end of the research for this thesis (Widener et al., 2013). The present study supports the use of such tools for this subject area. The GEM indicates

that it is possible to effectively replicate the result and timing of a hurricane evacuation through an ABM. The binary nature of the yes/no decision to evacuate means a model is an appropriate method, while the social nature of evacuation decisions lends itself to ABMs. Moreover, as the previous chapter argued, not having the data on all aspects of the evacuation need not be an obstacle in the use of an ABM. Indeed one of the main uses of an ABM is for data generation; it can be a way of undertaking empirical research through simulation. Although the model would have been more accurate with further empirical data, the type and size of the social network, as well as the strength of the subjective norm can be explored through sensitivity testing. As empirical and theoretical considerations were taken into account, it was possible to make the agents reactive, proactive and communicative. However, as the inputs to the model are case specific, the next time that Galveston is threatened by hurricane it is uncertain that the GEM would be accurate at simulating evacuation. The subjective evacuation attitudes are derived from statements which are directly related to Hurricane Ike and the events included are those which were deemed to be relevant for that unique hurricane. As the GEM produced non-linear results when the strength of the subjective norm was altered, it is probable that it does produce emergent results. This means that an ABM can potentially give a different understanding to evacuation behaviour that other models cannot through the inclusion of subjective evacuation attitudes and subjective norms.

7.8 The integration of a Q study and an ABM in a case study

The case study was an effective way to investigate hurricane evacuation as it enabled an in-depth investigation into how decisions were made. The case study approach was context specific as the evacuation for Hurricane Ike, as for any hurricane, was characterised and defined by environmental and human factors. This is most obviously demonstrated by the unpredictable path of the hurricane, the exposed nature of the island, the history of hurricane evacuation on Galveston and the timing of the evacuation orders. The selection of the statements used for the Q study and the parameterisation of the events in the GEM exemplify how the context of the hurricane and evacuation was incorporated into the methods. It is true that the thesis is only

concerned with the experience of Galveston at the time of Hurricane Ike, so one must be careful when considering the generalisability of the findings. Nonetheless, this study supports the position of Flyvberg (2006) who believes that the case study has value in providing a nuanced understanding of a phenomenon.

An unwritten research question was how the two methods could operationalise the framework of the thesis, as to the author's knowledge a Q study and ABM have never been used in the same study. Both the Q Study and the GEM are methods which focus on subjectivity. By revealing their subjective evacuation attitudes, the Q study stresses the heterogeneity and agency of the participants while reducing researcher bias. On the other hand, any model, by its very nature will be somewhat positivist as it simplifies human behaviour. However, the GEM partially supports Füllsack's (2013) claim that ABMs can be constructivist, complementing the Q study. There are three reasons for this; firstly, as the GEM was parameterised with empirical data it represents the subjectivity of the residents of Galveston. Secondly, the agents are given the agency to interact with each other. The way in which this is modelled with probabilities means that interactions between agents encouraged evacuation, without making it inevitable, so the agents maintain their individual agency. Thirdly, the GEM produced emergent behaviour, which could not be predicted by the inputs to the model, exemplified by the non-linearity in the evacuation result when altering the strength of the subjective norm.

Nonetheless, it must be accepted that there is an inherent tension between the two methods, as even the most carefully designed ABM will be more positivist than a constructivist Q study. An ABM cannot be absolutely constructivist, but it can facilitate a constructivist research perspective by being combined with a constructivist method such as Q. This thesis therefore shows the utility of combining a constructivist approach (Q) in tandem with a more positivist modelling based approach (ABM) which both increases the validity of the latter, whilst simultaneously demonstrating the significance of the findings from the Q study by incorporating them into an evacuation model.

As Guba states, there is a strong belief that quantitative and qualitative methods should not be mixed (1990). In the same way there is an assumption that combining epistemologies is inherently wrong. It is the author's opinion that just as qualitative and quantitative methods can be combined, there is no reason why competing epistemologies should not be included in one study. As the methods were well suited to the research questions, and the GEM was designed to recognise individual subjectivity, the combination of methods brought synergy (Maxcy, 2003) to the thesis. The Q study and GEM are also complementary as they allow the transition from qualitative to quantitative data. The Q study initially uses qualitative techniques to get a deep, rich understanding of a person's subjectivity and the Q analysis turned this qualitative data into rigorous quantitative data. This quantitative data was the basis for the factor interpretation. The factor interpretations and interviews were used to define the key data in defining the four agent types in the model and parameterise the impact of events in the model. The Q study provided detailed analysis of the subjective evacuation attitudes present in the population, while the GEM synthesised this empirical data and considered its interaction with subjective norms at the island level. In this way the focus of the thesis evolves from a micro to macro-level investigation.

7.9 Limitations

Although the interviews were carried out two years after the hurricane, it is the opinion of the author that the participants were able to express their subjectivity in the days leading up to the landfall of Hurricane Ike effectively. However, although most of the participants claimed to recall clearly what they had been experiencing in the days leading up to the landfall of Ike, it is possible that some degree of slippage could have occurred as the level of media coverage and discussion that participants would have engaged in through the intervening time could have biased their retrospective assessment of their subjectivity at the time of Ike.

All of the Q sorts were carried out with people still resident in Galveston at the time of the study. This means that no interviews were performed with people who evacuated from Galveston and did not return. It has been shown that Galveston's population has

yet to recover as some residents have not returned (Xiao and Van Zandt, 2011). Therefore it is possible that the participants are not totally representative of the population at the time of the impact of Hurricane Ike. It is estimated that a significant proportion of the population which did not return to the island were forced to find another home as Galveston did not rebuild its damaged social housing (Xiao and Van Zandt, 2011). This means it is less likely that some of the most vulnerable residents at the time of the Hurricane Ike were included in the Q study. In an attempt to overcome this limitation, efforts were made to seek out participants from underserved communities through contacting local charities.

While the GEM effectively represented the observed evacuation behaviour of 296 evacuating Galveston residents and demonstrated the possible effects of changes in attitudes, subjective norms and social networks on city evacuation rates, it also has limitations. The Q study was conducted on forty participants, thirty-six of whom were used to generate the four subjective evacuation attitudes. This is a sufficient number to assert that the subjective evacuation attitudes exist on the island of Galveston as the statements came from the public sphere and through the sorting process the participants operationalised their subjectivity (Brown, 1980). However, due to the small number of participants, it is impossible to claim that these are the only subjective evacuation attitudes which exist. It is also impossible to know how many residents on Galveston hold each of the four subjective evacuation attitudes. Q is a statistically rigorous method, in that it reveals subjective constructs which exist in a community, but *not* their prevalence. As a result, the GEM was populated with the four subjective evacuation attitudes in the approximate proportions from the Q study. The probability that each subjective evacuation attitude will evacuate was also derived from the Q study. These are obviously major assumptions. It was initially decided to use a survey to attempt to find the proportion of the Galveston community which identified with each subjective evacuation attitude. Unfortunately due to time and resource constraints this was not undertaken. This is the main reason why the GEM should not be considered a predictive model.

A second reason why the GEM should be considered indicative as opposed to predictive is that while the environmental cues are based on historical events and the probabilities used for evacuation are informed by empirical data, the networks are artificial. Despite the benefits of using the GEM to perform a sensitivity test on the impact of subjective norms, the use of further empirical data would enable the model to have better predicative ability. However, as discussed earlier one of the reasons for developing the GEM is due to the difficulties in ascertaining the strength of the subjective norm and the size and type of social network from traditional methods.

Geocoding was not used to place the agents in their true locations on the island. This ignores the possible differences in evacuation rates between different areas of the island. As the seawall only protects the East End of the island, the West End is more exposed to storm surges, and indeed was more affected by Hurricane Ike than the East End. It could be argued that residents of the West End are more likely to either hold the attitude of Citizens and evacuate when they are told to do so, or Pragmatists and evacuate when they see the water level rising. As the small world network is defined by space, a realistic representation of the location of households could produce different results, as the subjective norm might spread at a different speed.

It is also true that other combinations of parameters could have resulted in a similarly accurate evacuation result. For example in the GEM, the surge which occurs in the calibration data on the morning of September 10th is covered by the diurnal surge. For this reason it was decided that it was unnecessary to include the impact of an event on the 10th. From the available data, it is impossible to know if increased evacuation on this day was as a result of an increased diurnal surge, or as a result of an event such as the voluntary evacuation order for the West End of the island. The GEM could have been modelled with a diurnal surge occurring on only the 11th and 12th, but the Q study did not suggest that any other event encouraged evacuation sufficiently to parameterise another event. For this reason it was decided to model the diurnal surge over the 10th, 11th and 12th.

The calibration of the GEM was undertaken sequentially; the underlying motivation was included, then the diurnal surge was parameterised before the impact of events was added. Finally the type and size of the social network was included in addition to the strength of the subjective norm. This is a valid way of parameterising the model, but another way would have been to alter the parameters simultaneously. This would have brought about a different result and it is possible it might have more closely matched the calibration data.

Perhaps the most serious limitation with the GEM is the lack of external validation. This is frequently a problem when designing an ABM when there is not an enormous quantity of data available. In the case of Galveston and Hurricane Ike, it is impossible to find suitable validation data as the hurricane only occurred once. Consideration was given to comparing the results of the GEM to the evacuations from another hurricane, but this would not work as each hurricane has its nuances and each population is differentiated - as the Q study showed. As a result the GEM was not validated, only compared to the calibration data.

7.10 Conclusion

This thesis suggests that subjective evacuation attitudes are one way of explaining a person's hurricane evacuation decision. The Q study revealed that these attitudes are differentiated within society, with the result that people faced with the same or similar risk information make different evacuation decisions. It is likely that each of the four risk paradigms (technical, socio-economic, psychological and cultural) discussed in the literature review can go some way towards explaining the diversity of subjective evacuation attitudes. However, it seems that only the technical and socio-economic approaches are recognised by current policies designed to maximise evacuation rates. These policies are based on a simplistic and limited definition of what a rational decision maker does when at risk of an approaching hurricane. This study does not prove that subjective evacuation attitudes are necessarily more important than other factors, but that it is one way of understanding evacuation.

If evacuation is understood as a choice, then agency can be recognised at a personal level, whilst still recognising the influence of structural factors and the need for improved communication. This way of conceptualising the four types of subjective evacuation attitudes has the potential to inform policy in important ways that can overcome the shortcomings of past policy approaches which characterise everyone as conforming to some kind of objective homo economicus type being. Such an understanding could eventually facilitate increased evacuation rates.

The thesis also demonstrates that island-level evacuation results can be explained through the creation of an ABM. By parameterising the GEM with empirical data and real life events, the GEM was able to approximate the calibration data for the evacuation result and timing. By including the impact of subjective norms, which are communicated through social networks, the evacuation result more closely replicated that of the calibration data. As there was little data on the subjective norms or social networks for Galveston it was necessary to use theory and sensitivity testing to generate a plausible parameterisation. The successful creation of the GEM demonstrates the compatibility of a Q study and ABM; two tools with a focus on subjectivity. It also showed the ability of an ABM to be built with a combination of empirical data, theory and sensitivity testing. The GEM also supports the use of the TRA (Fishbein and Ajzen, 1975) for explaining community-level evacuation through subjective evacuation attitudes and subjective norms.

The GEM also suggests alterations to subjective evacuation attitudes and subjective norms would have a significant impact on island-level evacuation behaviour. If it is assumed that subjective evacuation attitudes can change, there can be large changes to the overall evacuation result. This could occur as the Believers are somewhat similar to the Citizens, while the Individualists share commonalities with the Pragmatists. The impact of subjective norms was altered through three distinct means. Firstly, the size of the social network in which residents live and communicate was increased. This could happen through the increased use of social media, enabling residents to communicate with more people. Secondly, the type of network in which the communication takes places was changed. It is assumed that at present Galveston

represents a small world network, and variations of the GEM demonstrated that if a random or scale free network developed then evacuation would increase. Finally, the strength of the subjective norm was altered. This could occur if either beliefs about peers' attitudes changes, or if the desire to conform to those attitudes changed. This could occur if peers apply more pressure encouraging evacuation. The impact of varying the parameters of the model demonstrates a hurricane similar to Ike could have a very different evacuation result assuming some small changes in society. These experiments suggest further research is required to ascertain the impact of social networks and subjective norms and how policy could utilise them to promote higher rates of evacuation. The final chapter of the thesis addresses some of these avenues for future research.

Chapter 8: Conclusion

8.1 Introduction

The thesis began by arguing that the literature on hurricane evacuation tends to highlight technical and socio-economic reasons for non-evacuation. These exogenous explanations (Adger et al., 2008) are popular with policy makers as they are more easily understood and can be potentially ameliorated through policy. Exogenous explanations have led to a pair of assumptions about evacuation behaviour in Galveston, Texas. Firstly, the technical paradigm assumes that rational beings will evacuate when under risk; therefore non-evacuation is explained through a failure of risk communication. The solution from this position is to concentrate on improving risk communication, which in Galveston includes the One Call Reaches All programme; an automated multi-media communication of hurricane risk information. The socio-economic paradigm assumes that those who do not leave are constrained by demographic factors. As such policies to improve evacuation rates include resilience building programmes and City funded evacuation. School buses are laid on to evacuate people to Austin, and food and medical equipment is also supplied. These policies are useful and no doubt do raise evacuation numbers, however hurricane evacuation rates for Galveston and other US coastal cities rarely rise above 70-80% of the affected population. This thesis argues that existing hurricane evacuation policies do not result in full evacuation as they are built on exogenous approaches which do not fully capture the complexity in society.

The research for this thesis originated with the investigation of endogenous explanations of risk (Adger et al., 2008). It was decided to investigate the psychological and cultural factors which impact on evacuation decisions as this field has been comparatively neglected. The literature review also revealed the lack of studies on the

impact of subjective norms on evacuation decisions. As a result, the methodological framework was built around the TRA, which postulates that decisions are made from a combination of attitudes and subjective norms (Fishbein and Ajzen, 1975). Sheeran's (2013) adaptation of PMT (Rogers et al. 1983) was incorporated into the TRA in order to give a fuller definition of attitudes. The evacuation from Hurricane Ike on Galveston, Texas was selected as an ideal case study. There were several reasons for this. Galveston is a relatively affluent area, meaning that the socio-economic factors which characterised the evacuation from Hurricane Katrina were likely to be of less importance, meaning it was more likely to find subjective explanations for evacuation behaviour. Additionally, it was possible to obtain survey data about the evacuation from an existing study (Van Zandt, 2010). It was then necessary to select suitable research methods; a Q study was selected as a tool to recognise a person's subjectivity (personal viewpoint on an issue) or attitude, while an ABM was selected as the ideal tool to investigate the impact of subjective norms. This meant that the thesis was a mixed methods study using a mainly qualitative tool (Q) which fed into a quantitative tool (ABM).

The Q study was carried out with forty people resident in Galveston at the time of Hurricane Ike. Thirty-six of the participants identified with one of four subjective evacuation attitudes. There were nineteen Citizens who generally evacuated and were influenced by the mandatory evacuation order, eight Individualists who for the most part did not feel sufficiently at risk to necessitate evacuation, four Pragmatists who evacuated when thought it was dangerous to stay and five Believers who mostly stayed as they felt they were protected or wanted to stay and help others. The GEM was designed as an environment which was populated with agents with the subjective evacuation attitudes revealed in the Q study. The agents were designed to be proactive and reactive with their evacuation decisions, and communicative as they were connected through a social network. Agents evacuated due to an underlying hourly rate, the time of day, relevant events taking place or through being influenced by the subjective norm. The GEM demonstrated how island-level evacuation might take place. Sensitivity tests were then performed on the parameters of the model in order to investigate the impact of changes in the proportion of each subjective

evacuation attitude, the strength of the subjective norm, and the size and type of the social network. These experiments showed how slight changes in attitudes, norms and networks in the future could have significant impacts on the evacuation result.

8.2 Methodological contributions

The following section will briefly outline the contributions which this thesis has made. Both Q method and ABMs are currently outside of the mainstream in Geography and Environmental Sciences, but their use is spreading. This thesis demonstrates their utility for the investigation of hurricane evacuation and the methodological innovation of their combination. This thesis has shown that a Q study can be an effective tool to reveal subjective evacuation attitudes. Traditionally Q studies have been used to unveil subjectivity (Brown, 1980) and have also been used to unveil socio-environmental interactions (Ockwell, 2008), but to the author's knowledge they have never been used to investigate hurricane evacuation. Through the careful sampling of the statements to be used, the Q study effectively captured the interaction of psychological, cultural and other factors. Due to the reflexive nature of the Q study, it can be claimed that the Q study minimised researcher bias and as such the four factors revealed did represent the operationalisation of the participants' subjectivity.

The use of ABMs for the investigation of subjective norms and social networks is an established field (Macal and North, 2010), although the use of an ABM to simulate macro level hurricane evacuation is still new. The GEM contributes to the niche established by Widener et al (2013). They conducted similar research on an ABM to simulate hurricane evacuation, of which the present author was unaware until approximately a year before submission of the thesis. The present study takes a different approach to Widener et al. in two main ways. The Widener et al. model is based on a hypothetical evacuation; this means there is a large degree of speculation in the parameterisation of the model which is mainly based on theory and socio-economic data; as a result it is a positivist approach. In contrast, the GEM combines theory with empirical data to build the model. The GEM managed to approximate the double s shaped evacuation curve of the calibration data effectively by including

empirically observed parameters to add to an underlying mean hourly evacuation rate. This was achieved through including the impact of surges in evacuation during daylight hours and the impact of events which influenced evacuators.

Secondly, the way in which the subjective norm is modelled is different. In the GEM, like the Widener et al. model, the size and shape of the social network and the strength of the subjective norm is parameterised through theory. The difference between the two models lies in the way in which agents are persuaded to leave by the members of their social network. In the Widener et al. model, the agents are compelled to leave once a determined number of people in their network have left. This means that their agency is constrained as their actions are dependent on the actions of others. By way of contrast, the agents in the GEM are advised not compelled to evacuate, thus maintaining personal agency. These differences mean that the subjectivity of the Q study is carried over into the GEM, because the agents in the model retain their personal agency.

This thesis suggests that subjective norms and social networks can impact on decisions as the introduction of the subjective norm successfully reconciled the differences between the calibration data and the GEM. It also shows that subjective norms and social networks can be parameterised through sensitivity testing the GEM. This is important as it is difficult to empirically investigate their structure and strength with conventional research tools (Christensen and Ruch, 1980). Through changing the proportions of the agents, the size and type of the social network and the strength of the subjective norm, the GEM can be used to investigate how changes in attitudes and the way in which the subjective norm is communicated could result in increased evacuation.

The combination of a Q study with an agent based model has not been undertaken before to the author's knowledge, probably as they seem rather disparate methods. As the ABM was partially parameterised with data from the Q study, the thesis demonstrates the compatibility of the two methods. The micro level qualitative data produced from the Q sorts is turned into quantitative data through the factor analysis.

This quantitative data is used to generate the factor interpretations which are used as the basis for populating the GEM with four distinct agent types representing the four distinct subjective evacuation attitudes. The GEM produced macro-level data, showing how these subjective evacuation attitudes and subjective norms operating through social networks might impact on island-level evacuation. In bringing these methods together, the thesis addresses the need for interdisciplinary research on evacuation decision making (FEMA 2010) and demonstrates how the social sciences can help to develop more robust evacuation models (Murray-Tuite and Wolshon, 2013).

8.3 Theoretical contributions

The research problem which was set out in chapter one was the following:

> Despite warning, why do a significant minority of affected residents not evacuate from hurricanes?

This thesis has answered this question by convincingly demonstrating the value of a more constructivist approach to understanding evacuation. It has shown the possibility of explaining differentiated hurricane evacuation behaviour through the study of subjectivity, specifically subjective evacuation attitudes and subjective norms. This finding challenges traditional, positivist understandings of hurricane evacuation which still tend to focus around the technical and socio-economic paradigms; explaining non-evacuation through the failure of risk communication or structural factors. The findings of the thesis emphasise the necessity of taking a more constructivist perspective which understands that decision making is subjectively constructed and plays out within the broader context of subjective norms which are communicated via social networks. Therefore this thesis contributes towards addressing the imbalance in the academic literature which tends to focus on “exogenous” explanations for failure to adapt to climate related hazards (Adger et al. 2008). This thesis does not claim that the technical and socio-economic ways of understanding risk should be discarded; risk communication and evacuation assistance are vital for increasing evacuation rates. Instead such approaches need to be complemented by constructivist approaches.

The Q study strongly rejects positivist assumptions that people understand hurricane risk in the same manner and have the same attitudes towards evacuation. Instead the Q study suggests that a constructivist position can reflect the importance of subjective psychological and cultural factors for explaining personal evacuation decisions as most of the Citizens and all of the Pragmatists evacuated, while most of the Individualists and Believers did not. The GEM showed how these subjective evacuation attitudes could lead to an island-level evacuation result when the subjective norms and the social networks in which they operate were considered. This demonstrates the influence of peer pressure on the decision to evacuate as the GEM only replicated the calibration data when the subjective norm was introduced, supporting the idea that evacuation decisions are social decisions (Taylor, 2009).

This thesis also supports the use of the TRA (Fishbein and Ajzen, 1975) used with Sheeran et al.'s (2013) revision PMT (Rogers et al., 1983) as a framework for understanding risk based decisions. More specifically, the thesis supports the use of the TRA in the investigation of hurricane evacuation supporting the work of Kang et al. (2007). The TRA was found to be the ideal framework to emphasise the subjectivity inherent in the decision to evacuate. As hurricane evacuation was seen to be an action in which volition was not constrained, it was unnecessary to use a different framework such as the TPB (Ajzen, 1991) which includes perceived behavioural control. Instead this concept can be subsumed into attitude formation, as attitudes are formed in part by a coping appraisal.

8.4 Empirical contributions

This study gives new insight into Galveston's evacuation during Hurricane Ike. Firstly it showed that on Galveston at the time of Hurricane Ike, members of the population held different subjective evacuation attitudes. The Q study highlighted four distinct subjective evacuation attitudes which go some way to explaining evacuation results. Residents who held one of two attitudes were likely to evacuate, while residents holding either of the other two attitudes were likely to stay and weather the storm.

Citizens tended to evacuate as they were influenced by official warnings while Pragmatists evacuated after making a subjective assessment of the risk in staying. This meant that on average the Pragmatists left later than the Citizens. Individualists tended not to evacuate; like Pragmatists they made a subjective assessment, but felt it was unnecessary to leave. On the other hand the Believers tended to be influenced by their faith. Some of them believed that their religion would protect them, another felt a need to stay and help others less able to help themselves in the aftermath of landfall.

The GEM was able to recreate the shape and timing of the evacuation curve from the calibration data, therefore it indicates how the evacuation from Hurricane Ike might have taken place. The final evacuation result is modelled as a combination of evacuation triggered by an underlying hourly probability to evacuate, an increased probability of evacuating during the daytime, the impact of salient events and the subjective norm encouraging evacuation.

The alterations which were made to the parameterisation of the GEM give an indication of how island-level evacuation could be different in the future. If the proportion of residents that can be described by each of the subjective evacuation attitudes were to alter, there could be a significant change in the island level evacuation result. In a similar manner, it was shown that changes in the strength of the subjective norm or size or shape of the social network could also have an effect on evacuation rates for Galveston. As the sensitivity testing of the strength of the subjective norm produced asymmetric and non-linear results, the GEM seems to exhibit emergent properties as it simulates behaviour which is not a direct function of the inputs of the model.

8.5 Policy recommendations

The results of this study can be useful for policy makers because as the Hurricane Ike Post Storm Assessment noted ‘better knowledge about the attitudes and potential behavioral response of coastal residents is an important first step towards designing relevant educational and evacuation programs’ (FEMA 2010, pp.129-130). As discussed

above, the Q study revealed that subjective hurricane attitudes on Galveston are differentiated. The existing policy for hurricane evacuation is based on the assumption that residents think as rational beings as defined by the kind of rationality reflected in neo-classical economic theory. If residents did think as homo economicus suggests, then the One Call Reaches All programme would mean that everyone was alerted to the danger and would want to evacuate. Those who could not leave independently could leave with the buses that the city provides.

Conversely, this thesis demonstrates that there are clearly a wider range of subjective evacuation attitudes than policy makers currently assume and account for. If policy makers continue to assume that people will evacuate based on warnings, it is likely then the same disappointing rates will result. Those members of the community who think like Citizens are likely to evacuate the next time there is a mandatory evacuation order and those who think like Pragmatists will probably evacuate when they perceive themselves to be at risk. However, policy should be more concerned with the members of the community who think like Individualists and Believers. It would benefit the island of Galveston if there were further understanding of their decision making. Policy makers need to recognise and validate these worldviews and build trust through engagement and public participation in hurricane policy. It is possible that eventually through appealing to the Individualists' sense of independence and the Believers' religious faith evacuation rates could increase.

It is also important to note that it is unlikely that 100% evacuation will ever be achievable in a democracy. Although legally people could be removed by force, it is unlikely to be considered desirable by political leaders or the electorate. The Q study suggests that a sizeable minority of residents of Galveston are likely to stay on the island despite any warnings which are issued, and believe that it is not the business of government to intervene. Policy makers should therefore be more concerned with understanding, and possibly providing for this population when they do not evacuate.

In addition, the thesis has demonstrated how subjective norms, operating through social networks, also have a role to play in evacuation. The GEM suggests that further

investigation into subjective norms and how they are spread through social networks would be useful to policy. The previous chapter suggested how changes in subjective evacuation attitudes, subjective norms and social networks could result in increased evacuation at the island-level. If more people on Galveston adopted the subjective evacuation attitudes of Citizens and Pragmatists instead of those of the Individualists and Believers then more evacuation would result. Additionally, if the strength of the subjective norm encouraging evacuation or the number of contacts in a social network increased, or if the type of social network changed there would also be a higher rate of evacuation. As it is the stated aim of government to encourage evacuation (FEMA, 2010), further policies which consider subjective evacuation attitudes and subjective norms are warranted. The "Ike Dike", a proposed engineering solution to prevent flooding, is years away and it is uncertain as to whether it would solve the problem, therefore the role of interdisciplinary research for improving policy should not be ignored.

8.6 Opportunities for future research

The findings which have emerged from this thesis present various opportunities for future research. The four different types of agents which comprise the simulated residents are based on the subjective evacuation attitudes revealed by a Q study of 40 residents. Although the proportion of residents in Galveston who load exclusively on each subjective evacuation attitude is unknown, the GEM uses the proportions from the Q study to replicate the actual evacuation curve. Additionally the probabilities that agents with certain subjective evacuation attitudes will evacuate was also derived from the Q study data. To more accurately parameterise the model, it would be necessary to conduct a study on a larger sample of residents to measure the proportions that load on specific attitudes. This could possibly be achieved through extending the Q study to a larger population, but a more practical way would be to use the Q study to design a survey (Danielson, 2009). Such a survey could check the extent to which these worldviews are held across the population of Galveston, and the relative prevalence of each.

Further investigation would also be useful in order to investigate whether there is any correlation between worldviews and socio-demographic data. For example, both the Citizens and Believers, and the Pragmatists and Individualists shared traits. The Citizens and Believers were more likely to be ethnic minorities and less well educated and with lower incomes. In contrast the Pragmatists and Individualists were mainly Caucasian, better educated with higher incomes. It is important to find out what is behind these commonalities in order to explain why an African American is likely to be a Citizen who evacuates or a Believer who stays? If this pattern were repeated in a survey, it would enable targeted research and eventually policy.

It might also be useful to investigate whether the groups identified in the Q study as sharing the same subjective evacuation attitude are members of the same social network or of networks of differentiated shapes and sizes. Further development of the model could then involve varying the social networks accordingly. A more refined version of the GEM could also help to articulate a difference between “general” and “specific” referents as proposed by Trafimow and Fishbein (1994). This idea focuses on the distinction between those members of the social network such as family members and spouses who are believed to have a greater influence than others. This distinction between members of a social network has been investigated by Hasan (2011). The Q study did provide some support for this, with one or two of the evacuators stating that they would have stayed and weathered the storm had they not been pressured into leaving by an immediate family member. These considerations were not included in the GEM as it was deemed preferable to err on the side of simplicity owing to a lack of data to support these claims.

Future research with Q studies and ABMs represent exciting opportunities for methodological development. A Q study could be used to ascertain subjective evacuation attitudes in other geographical areas, both in the Gulf of Mexico and other areas threatened by hurricanes. If a Q study were applied to other hurricane threatened communities, it would need to be adapted to the particular characteristics of the hurricane and community in question. It would be necessary to construct an entirely new set of statements which reflect the opinions held by the community

about the hurricane in question. Although there are commonalities in hurricane evacuations, the issues for each community will vary depending on factors such as physical geography, human geography and the meteorology of the hurricane. Although it is unlikely that the design and parameters of the GEM could be used to simulate the evacuation of another community from another hurricane, the innovative ways of agent design and parameterisation could be replicated. In the GEM it was assumed that the most salient events influencing the decision to evacuate were the mandatory evacuation order and the onset of flooding. If adapting the GEM, a different set of events might be needed in order to capture the specificities of the hurricane, the environment and the community in question.

The combination of a Q study producing data from which to build an ABM could also be replicated. The same methods would be of use for the investigation of evacuation from a different hurricane; in this way it would be possible to validate the GEM by using data from another hurricane. It is also possible that the methods could be used for the investigation of evacuation from other natural or man-made hazards or environmental stress. Testament to the utility of the methods is that an ongoing European Community funded project in Vietnam has adopted the combination of a Q study and ABM to investigate climate change related migration out of the Mekong Delta (Trapped Populations, 2014).

This thesis challenges existing understandings of hurricane evacuation which still tend to focus around the technical and socio-economic paradigms, explaining non-evacuation through the failure of risk communication or structural factors. It has demonstrated that it is possible to explain differentiated hurricane evacuation behaviour through the study of subjectivity, specifically subjective evacuation attitudes and subjective norms. Therefore this research has shown the importance of more constructivist perspectives in the understanding of how risk decisions are made. It is possible that incorporating a more constructivist approach into existing theoretical approaches could further the understanding of evacuation in the face of natural and man-made hazards. The successful integration of the methods and research framework selected for this thesis suggests that other theories of risk could be

similarly developed to move away from positivist based methods and assumptions and towards reflecting the subjectivity inherent in personal and social decisions.

This thesis supports endogenous explanations for hurricane evacuation, and it would be useful for further studies to implement other methods to investigate the psychological and cultural paradigms of hurricane evacuation and research how these subjective evacuation attitudes are formed. As discussed in the methodological chapter, it is likely that such methods would initially be qualitative, in order to get a deep understanding of the processes which impact upon attitudes. The Q study suggested there is a diverse range of reasons which may cause people to decide to stay and weather the storm. As the Q study is context specific, it is unlikely that Individualists and Believers exist in other communities as defined by their factor interpretations for Galveston and Hurricane Ike. However, it seems likely that some of their key characteristics are present in other communities. It is probable that for any hurricane the reasons for non-evacuation include the Individualists' lack of trust in the authorities, and lower perception of risk and the Believers' faith in a higher being and the desire to help others. It would therefore be useful to investigate further the relationship between the subjective evacuation attitudes and the evacuation decision.

There has been a surge in academic interest in the role of social media before, during and after hazards (Crowe, 2011). This area is particularly promising as data on social media posts can be obtained relatively easily (McClendon and Robinson, 2013). There is clearly room for more research on the flows of information, from which hypotheses could be made about the impact of subjective norms. This thesis has shown that not only can ABMs be used to simulate the impact of social networks, they can also be used to perform experiments to investigate the strength of a subjective norm and the social networks which they inhabit.

The GEM enables the testing of which configurations of social networks and subjective norms can produce realistic evacuation results. To develop a more accurate model for making predictions it would be necessary to empirically investigate which social networks exist on Galveston. It would be difficult to ascertain this through traditional

methods, but recent research centred on the use of social media in disasters could be used to construct non face to face social networks. It would also be useful to find out how prevalent opinion leaders are. As the Q study revealed heterogeneity of subjective evacuation attitudes, it is simplistic to assume there is homogeneity in the size of social networks. Again research on social media could provide the number of people regularly contacted, but to find out about face to face contacts would be more problematic. As highlighted in the literature review, it is extremely difficult to ascertain the influence of a subjective norm on a particular behaviour. In fact this was one of the reasons that it was decided to use an ABM to simulate the effect of different strengths of subjective norm on the island-level evacuation result. There have been experiments on the impact of subjective norms on decision making and to a lesser extent the impact on hazard related behaviour, but this is an area which would benefit from further research.

The results of the variations of the GEM suggest that small adjustments in the proportions of each subjective evacuation attitude can lead to large differences in island-level evacuation results. Further research could attempt to identify how these attitudes could be better understood. For example, in the population variation experiment of the GEM it is assumed that if some Individualists thought more like Pragmatists and some Believers thought more like Citizens then evacuation rates could increase significantly. It would be useful for policy makers to investigate how such a change in attitudes could be promoted; perhaps through engagement with the community as discussed in the previous chapter.

The GEM found that the evacuation result increased as the number of people in the social networks increased. The structure of the social network also impacted on the evacuation result, with the least spatially constrained networks leading to more evacuation. There needs to be further research on how an increase in the size of the social network or a change in its structure can be facilitated through policy, or how this process might happen organically through the development and adoption of social media. There is a need for more research on the role that social media plays in emergencies (Carter et al., 2014), and the methods used for such research need to be

innovative and multidisciplinary to capture the subjectivity and complexity of behaviour.

8.7 Conclusion

Anthropogenic climate change will impact on extreme weather events. Sea level rise will act as an intensifier for storm surges as land will be more easily inundated. An increase in average sea temperatures means that the ideal climatic conditions for the development of storms will occur more often, possibly resulting in more intense hurricanes. It is also possible that under a changed environment, hurricanes could impact on a wider range of locations, seemingly exemplified by Hurricane Sandy which impacted much of the Northern Atlantic coast of the USA. Meanwhile the number of people living in areas threatened by hurricanes is increasing both in the developed and developing world. If the number of fatalities and injuries is to be reduced in the future there is a need for more effective policies.

This thesis has shown that innovative methods can be used in the study of hurricane evacuation at both the micro and macro level. The Q study facilitated the investigation of individual choices to evacuate or stay and weather the storm based on an understanding of participants' subjective evacuation attitudes and as such responds to Adger et al.'s (2008) call for more research into endogenous barriers to responding to environmental risk. The GEM was an ideal method for synthesising the impact of these individual decisions, simulating how people impact on each other's decisions and testing how small changes in subjective attitudes and subjective norms could result in significantly different evacuation results. As such it demonstrated the potential for this method for the investigation of social decision making.

This thesis represents a fundamental challenge to positivist policy approaches and clearly demonstrates the value of a more constructivist approach to understanding evacuation based on analysis of subjective evacuation attitudes and subjective norms. Innovative tools such as Q and ABMs have a role to play in investigating environmental

risk, by allowing the study of behaviour from new and valuable perspectives. Hurricane evacuation policy can only benefit from incorporating findings from such studies, complementing existing programmes that tackle the problem of non-evacuation from purely technical and socio-economic perspectives.

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